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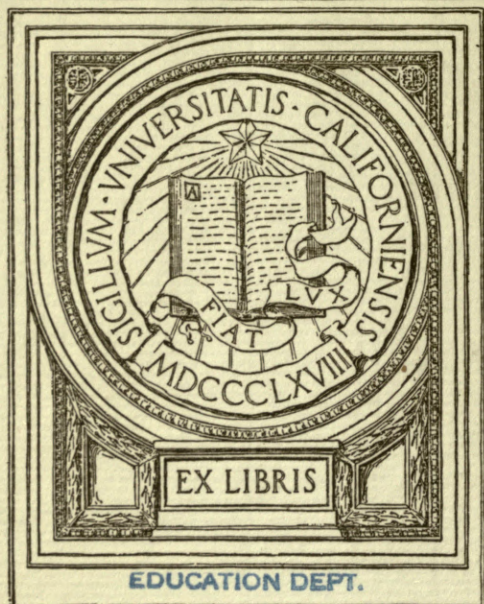


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A LABORATORY MANUAL FOR GENERAL SCIENCE

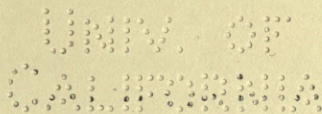
CALDWELL - EIKENBERRY - PIEPER

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L. A. Williams



EDUCATION DEPT.

A LABORATORY MANUAL FOR WORK IN GENERAL SCIENCE



BY

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THE SCHOOL OF EDUCATION, THE UNIVERSITY OF CHICAGO

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PREFACE

Laboratory work and the experiences of home and school furnish an important basis for the course in general science. The following outlines for experiments and demonstrations have been developed so as to include the exercises which have proved most valuable for use in the first year of the high school. The outlines are the result of the coöperative work of several high-school teachers through a period of years, and have been tried with more than a thousand pupils. Experiments other than those here included have been tried, but through constant trial, elimination, and addition the work has assumed its present form.

It is the purpose of the outlines to direct the pupils into the habit of finding out about many kinds of common problems in science. To do this in the best way common materials are used for experimentation, since common and simple phenomena are likely to be more educative for young pupils than those which are uncommon and complex. The materials needed are listed in connection with each exercise. It is hoped that teachers will encourage pupils to use their own initiative in devising new ways to perform the experiments, as well as in working out additional problems which are sure to be suggested in the discussion of the experiments here outlined. At the close of the directions for work, one or more additional problems are suggested, and the use of these as topics for discussion will make the work more valuable.

The exercises have been planned so that each one requires a shorter period of continuous attention than is usually true in the more advanced laboratory work in high-school science. Experience has shown that first-year pupils work more effectively when the units of work assigned are relatively short and definite. This plan results in a larger number of exercises than would be used in a more advanced course in science. In many cases, however, two or more exercises may be performed in a single laboratory period.

Supplementary or alternative experiments, which sometimes require more complex apparatus, are often given. These supplementary experiments are indicated by the same arabic number as the preceding experiment, but with a letter added. Thus 22 A is an experiment which may be used in addition to or instead of Exercise 22.

When diagrams, charts, or graphs are called for, the proper kind of paper for such work is provided.

The Directions to Students should be carefully read by teacher and pupils. These directions, in addition to giving instructions about how to proceed, are designed to develop interest and give the proper point of view.

The outlines are provided in both bound form and in loose-leaf form. The loose-leaf form makes it possible for teachers who wish to vary the order to do so.

THE AUTHORS

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APPARATUS LIST

It is believed that the following list contains all the apparatus and supplies, excepting a few very common materials, that are necessary for the laboratory work in general science. More elaborate apparatus could be specified in many cases, but it is believed that there is a positive educational gain in using simple apparatus. It will be noted that in many cases it is possible to use familiar appliances from the household, farm, and shop, and these should be used wherever practicable. It is taken for granted that the school possesses certain common equipment such as hammer, saw, nails, tacks, pliers, cork and rubber stoppers, and glass and rubber tubing.

The prices attached are approximate only and are based upon retail prices as found in retail stores and in dealers' catalogues. Schools should be able to secure a discount of from 10 to 25 per cent from these prices. The elimination of the most expensive pieces of apparatus will not require the omission of many exercises.

GENERAL APPARATUS

1 air pump (if the laboratory is supplied with running water, it will be cheaper and more convenient to use a filter pump, price \$1.75) . . .	\$4.00	100 filter papers (circular, 13 inches in diameter)	\$0.70
1 air-pump platform	5.50	1 globe, brass, air-weighing (glass flask may be substituted)	2.50
1 or more aquaria (battery jars may be used, \$0.65 each) . . . . .	.65	1 roll labels (Dennison's perforated paper labels No. 221) . . . . .	.45
1 balance (Harvard trip scale or other balance weighing to 0.1 gram)	8.00	1 or more magnifiers (\$0.50 each) . . . . .	.50
1 set balance weights (iron, 5 grams to 1000 grams)	1.60	1 lb. marble chips	
1 bicycle pump for inflating football . . . . .	.25	1 meter stick or yardstick . . . . .	.25
1 bladder glass	1.00	1 osmometer, Lyon's pattern, from Wm. Gaertner and Company, Chicago (glass thistle tube may be substituted) . . . . .	.50
1 barometer tube . . . . .	.33	1 cake paraffin or sealing wax . . . . .	.05
1 ball cord (linen) . . . . .	.20	1 protractor (brass, 5-inch) . . . . .	.20
1 piece charcoal		1 pail (galvanized) . . . . .	.20
$\frac{1}{4}$ lb. copper wire (No. 18) . . . . .	.15	1 glass pump model (may be constructed from lamp chimney, cork stoppers, wire, leather, and tacks, as described in Exercises)	1.65
1 roll cotton (absorbent) . . . . .	.20	1 coil picture wire (small) . . . . .	.05
1 clamp (wire test-tube holder) . . . . .	.10	2 pinchcocks (Mohr's medium-size) . . . . .	.20
3 (or more) dry cells . . . . .	.60	1 pinchcock, screw compressor . . . . .	.20
Maps of ports or waterways of local importance.		$\frac{1}{2}$ lb. parchment paper, medium weight . . . . .	.20
Price lists may be secured from the following:		Reports of local boards of health	
Coasts of United States: Coast and Geodetic Survey, Washington, D.C.		1 piece sheet rubber (dentists' rubber dam, 2 x 2 ft.)	.25
Great Lakes: United States Lake Survey Office, Detroit, Michigan.		1 rubber rod or ruler . . . . .	.10
Mississippi River: Mississippi River Commission, St. Louis, Missouri.		1 package starch . . . . .	.10
1 electrolysis apparatus (substitute may be made from bottle, stopper, and electric-light carbons as described in Exercises)	1.25	1 steam-engine model	2.25
1 football (borrow this from athletic department)		4 thistle tubes (15-inch stem) . . . . .	.48
1 funnel (glass, 8 inches in diameter) . . . . .	.30	1 piece tubing (glass, $\frac{1}{2}$ -inch diameter, 5 feet long) .	.40
		1 wire basket for test tubes . . . . .	.40
		Total	\$35.26

INDIVIDUAL APPARATUS

One or more sets of the following apparatus will be needed. Performance of experiments by individual pupils when practicable will require that the apparatus be duplicated. The number of duplicate pieces needed will depend upon the number of pupils in the classes and upon whether the experiments are to be performed by each pupil working alone or by groups of pupils.

1 Bunsen burner (alcohol lamps may be used if the laboratory is not supplied with gas)	\$0.30	1 pan (sheet-iron, such as a 6-inch frying pan) . . .	\$0.10
2 bottles (wide-mouthed, 6- or 8-ounce) . . . . .	.10	$\frac{1}{2}$ doz. plant pots, paraffined paper 3 inches high, $\frac{1}{2}$ cent each. (Earthenware pots may be used, but must be sterilized before using a second time. Paper pots are thrown away after using.)	.03
1 candle . . . . .	.05	1 ring stand and clamp for supporting apparatus . .	.90
1 cup (aluminum drinking cup, polished surface) . .	.10	1 spring balance, reading to 8 ounces and 250 grams .	.80
1 cylinder (graduated, 100 cc., for measuring liquids)	.70	1 piece tubing (glass, $\frac{1}{4}$ -inch diameter, 18 inches long)	.10
1 flask (glass, 6-ounce), with 2-holed rubber stopper to fit . . . . .	.25	1 thermometer (chemical) reading to 110° C. and 220° F.	1.25
1 dish (glass or earthenware, 3 or 4 inches in diameter, shallow form such as low jelly glasses) . .	.02	1 vial (shell vial) . . . . .	.02
1 drinking glass . . . . .	.03	Weather maps (free) from nearest Weather Bureau Station	
1 pulley (double) . . . . .	.45	Total (one set)	\$5.90
1 pulley (single) . . . . .	.26		
1 pan (granite ware, 6 to 8 inches in diameter) . .	.10		

CHEMICALS

1 bottle ammonia water (household ammonia) . .	\$0.10	Lime water. (Make when needed by slacking lime in water and filtering off the water. More water may be added to the residue in the bottle and filtered off later. Keep bottle tightly stoppered.)	
1 lb. acid, hydrochloric, commercial . . . . .	.35	4 oz. litmus solution	\$0.35
1 lb. acid, nitric, commercial . . . . .	.35	2 lb. mercury	2.00
1 lb. acid, sulphuric, commercial . . . . .	.30	4 oz. potassium chlorate . . . . .	.10
1 qt. alcohol, grain, 95 per cent . . . . .	.75	4 oz. sulphur (flowers) . . . . .	.05
1 oz. eosin, water soluble (red ink may be substituted)	.20	1 bag salt (coarse) . . . . .	.10
$\frac{1}{2}$ lb. formaldehyde (40 per cent solution) . . . .	.20	4 oz. vaseline . . . . .	.10
4 oz. ether (or chloroform) . . . . .	.35	1 lb. zinc (granulated, mossy, or scrap) . . . . .	.20
4 oz. Fehling's solution No. 1		Total	\$6.30
4 oz. Fehling's solution No. 2			
(Mix No. 1 and No. 2 in equal parts for use.)			
4 oz. iodine solution (tincture of iodine) . . . .	.30		

SPECIAL APPARATUS

The following pieces of apparatus can be secured from the other laboratories of the school if these are fully equipped, or in some cases they may be borrowed from citizens (these pieces are not used with sufficient frequency to justify purchasing for the general-science courses only):

Compound microscopes or micro-projection apparatus, slides, cover glasses.

Steam sterilizer. (The household type may be borrowed and is as satisfactory as the laboratory type. A sterilizer may be improvised by placing the object to be sterilized in a bucket of boiling water.)

A slated globe. (May be secured from the mathematics department or geography department.)

The expense of equipping a laboratory for general-science classes will vary according to the amount of dependence placed upon the laboratories already existing in the building. If these are well equipped and so located that their facilities can be used to the fullest extent, very little new apparatus need be secured, and the expense will be nominal.

If it is desired to equip the general-science laboratory quite completely and independently of other departments, the cost is essentially as follows, assuming that the school has secured the usual discounts:

1 complete set as above (not providing for individual laboratory work by the pupils)	\$40.00
1 complete set and 19 duplicates of the individual set	130.00
1 complete set and duplicates to provide for ten pupils or groups of pupils working simultaneously on many experiments	80.00

By borrowing the most expensive apparatus and pieces used only once or twice during the year from other laboratories and by improvising some pieces as suggested, the cost of equipment for a very satisfactory course with a large amount of individual experimentation may be reduced to \$30.00 or less.

DIRECTIONS TO STUDENTS

Each observant person is constantly noting occurrences in nature which he would like to have explained to him. A flying kite leads us to ask how it is made to fly. Boiling water in a kettle lifts the lid which covers it, and we want to know what causes the lid to rise. The tender stem of a plant pushes up through gravelly or hard-packed soil, crowding the pebbles and soil out of the way, and we ask how the delicate shoot, still uninjured, can move such solid bodies. A colony of ants makes its home in a field of corn; the corn is soon retarded in its growth, and we want to know what is taking place. A pupil visits a friend who is ill, and later the visitor may have the same disease as that which affects the friend. What has occurred? Many such questions concern our daily lives, and we are more intelligent and more efficient persons when we can answer some of these questions.

There are two good ways of securing answers to our questions. One way is to ask persons who know about these matters or to read what they may have written. The other way is to study the occurrence by means of further observation and experiment, thus trying to make the occurrence itself help to answer the question regarding it. It is the purpose of these outlines to use the latter method in answering some important questions, as well as to lead to new questions.

To secure the greatest good from an experiment it is necessary (1) to record the way in which the experiment is performed; (2) to state the facts shown by the experiment; and (3) to explain these facts, if an explanation can be made. When you have performed an experiment, write your statement of these three points as clearly as if your notes were intended to be read by a person who knows nothing about the experiment you are describing. Make diagrammatic outlines to represent the apparatus used, whenever such diagrams will help to make the process or results more clear. In all cases make sure that your work is concise, neat, and clear in its presentation of the facts and inferences from them.

LABORATORY MANUAL FOR WORK IN GENERAL SCIENCE

EXERCISE 1¹

DOES AIR OCCUPY SPACE?

Materials. A jar, a deep pan, or a pail; a drinking glass.

Directions. In a large jar or other available vessel pour water until the vessel is about three fourths full; then hold a drinking glass mouth downward in the hand and while holding it in this position, push it into the water until it is entirely covered with water.

Does the water fill all of the space within the glass?

Tilt the glass to one side, and observe what occurs. Hold the glass in a vertical position again, and observe the level of the water inside. Do these observations help to solve the problem of this exercise?

Additional problem. What is a diving bell, and how does it work?

¹ As stated in Directions to Students, page xi, each pupil should note exactly what is done in the performance of an experiment, and should observe what occurs, then try to explain what has occurred. The blank space following the directions is for use in recording these facts by means of sketches and descriptions.

EXERCISE 2

CAN AIR BE MADE TO EXCLUDE WATER?

Materials. Those of Exercise 1; also a short glass tube, or straw bent slightly at one end, or piece of rubber tubing.

Directions. Place the drinking glass under the water so that it is full of water. Then invert the glass so that the mouth is downward. With the straw or tube placed with the bent end directly under the mouth of the glass, blow through the tube. Explain what occurs.

Additional problem. Why is it that when a heavy rain falls after a long period of dry weather air bubbles arise from the soil?

EXERCISE 3

DOES AIR HAVE WEIGHT?

Materials. A football; a bicycle pump; a pair of balances.

Directions. Pump into the football all the air which can be forced into it without danger of bursting it. Weigh the football accurately and record the weight. Open the tube of the football and allow as much air to escape as can be done without allowing the football to collapse. Weigh accurately again. Compare and explain any difference between the two weights.

Additional problem. Do you think that a given volume of liquid air would weigh more or less than the same volume of ordinary air? Why?

EXERCISE 3 A

DOES AIR HAVE WEIGHT?

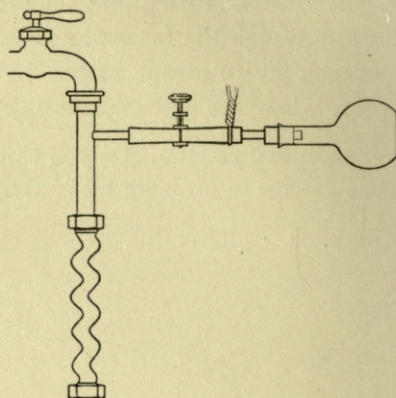
Materials. An air pump (an inexpensive filter pump may be used) ; a brass globe ; a bottle or flask.

Directions. This experiment may be performed by the teacher, but each pupil should make his own solution of the problem and write complete notes.

Pump the air out of a brass globe or other container as completely as possible, and close the stopcock. Weigh and record the weight of the globe. Open the stopcock to admit air, weigh again, and record the weight. Has the weight changed?

What is your answer to the question with which this exercise began?

If the brass globe ordinarily used for this purpose is not available, a bottle or flask may be used. This should be fitted with a one-holed rubber stopper, through which is inserted a short glass tube. A piece of thick-walled rubber tubing fitted with a pinch clamp will serve as a stopcock. The air may be removed by means of either an ordinary air pump or a filter pump. The latter is inexpensive and entirely satisfactory if water under pressure is at hand.



EXERCISE 4

HOW MUCH DOES A CUBIC FOOT OF AIR WEIGH?¹

Materials. The flask used in preceding exercise; a graduated cylinder (or a foot or metric rule).

Directions. Ascertain the cubic contents of the container used in the preceding exercise. If the container is spherical the diameter may be measured and the volume calculated; if it is of any other shape secure the volume by measuring the amount of water necessary to fill it. Considering this to be the volume of the air in the container, and using the difference in weights obtained in the preceding work as the weight of this air, calculate the weight of a cubic foot of air.

In your notes explain your method of work, and include in good mathematical form each step in your calculations.

A liter of air weighs about 1.293 grams. A cubic foot of air weighs 1.29 ounces or 36.61 grams. Knowing these corrected weights, how much error is there in your calculation? How do you explain the difference?

Additional problem. How can you determine the weight of the air in the room in which you are working?

¹ If the metric units of measurements are desired they may be substituted for the English units. Both systems of measurement should be made familiar by use.

EXERCISE 5

SINCE AIR HAS WEIGHT, DOES IT PRESS DOWNWARD AS OTHER
HEAVY OBJECTS DO?

Materials. A piece of sheet rubber (dentist's rubber) about 6 or 8 inches square; a bladder glass ("Elements of General Science," Fig. 5); an air pump (or a filter pump as described in Exercise 3 A, together with a pump platform).

Directions. Tie a piece of thin sheet rubber across the top of a bladder glass. When the rubber is first placed upon the glass, no pressure of the air upon the rubber is noted, because there is air both below and above the rubber. In order to know whether there is pressure upon the rubber, we may remove the air from beneath. To do this, place the glass upon the platform of an air pump and remove some of the air.

What are the results and your conclusions?

Additional problems. Why are we not conscious of the pressure of the air upon us?

With a hand placed over the bladder glass remove some of the air from the glass. Why is suction not a good name for the results observed when the air is partly removed from beneath the hand?

EXERCISE 6

IS AIR PRESSURE THE SAME IN ALL DIRECTIONS?

Materials. Same as in Exercise 5.

Directions. Using the same experiment as in Exercise 5, pump out part of the air and then close the stopcock so that no air can enter. Turn the apparatus on its side, and also upside down. In each case note whether the rubber is bulged inward in the same way and to the same extent. What is your conclusion?

Additional problems. Why does not the downward pressure of the air force a bucket or other object from one's hand?

What causes a rubber or leather "sucker" to adhere to a smooth surface? Will it adhere more readily to a smooth or a rough surface? Why?

EXERCISE 7

TO STUDY THE CONSTRUCTION AND OPERATION OF A MERCURIAL BAROMETER

Materials. Glass tube about one-quarter inch in diameter and 32 or 33 inches in length; a pound of mercury; a dish 2 to 3 inches in diameter.

Directions. The teacher may construct a barometer before the class as follows: Cut a glass tube about 32 or 33 inches long. One end of the tube should be closed, which may be done by heating until it melts. Fill the tube with mercury. Closing the tube with a finger, invert it in a cup of mercury. When the finger is removed, measure the height of the mercury in the tube above the level of the mercury in the cup. What supports the mercury? How could this apparatus be used to measure the weight of the air in different places and at different times?

Barometers constructed hurriedly as above are not accurate because some air bubbles adhere to the glass and finally get into the space above the mercury. In a well-constructed barometer this air has been driven out. Such a one, with graduation showing the height of the column in inches or centimeters, should be on the wall. It should be examined from day to day and a record kept.

Additional problems. In what ways and for what reasons will the column of mercury change when the barometer is taken high into the air or down into a deep mine?

If the column of mercury in a barometer is 30 inches high at sea level, how high will the column be at an elevation which has half as great air pressure as at sea level?

Incline the barometer tube to one side. Then measure the length of the mercury column, and also the vertical height of the upper end of the mercury above a point at the same level as that of the mercury in the dish. Explain the results.

EXERCISE 8

WHAT EFFECT IS PRODUCED UPON A VOLUME OF AIR BY A CHANGE IN ITS TEMPERATURE?

Materials. A glass flask or bottle; a one-holed rubber stopper which fits the flask or bottle; a glass tube about 18 inches in length; a drinking glass or other similar vessel.

Directions. Insert one end of the glass tube through a one-holed rubber stopper, then place the stopper in the neck of the flask or bottle. Hold the apparatus in an inverted position with the free end of the tube in a vessel of water. Warm the flask with the hands. What occurs? Keep the hands on the flask as long as there is any result. Then remove the hands, but keep the end of the tube under water and allow the flask to cool, noting what happens.

Explain the results you have seen. What have you learned about the behavior of air when heated? when cooled?

Additional problems. When an automobile tire has been pumped full of air in the early morning and then allowed to stand in the sunlight for some hours, it sometimes bursts. Why?

One type of glass fruit jar is sealed by applying the cap to the jar while the jar and contents are hot, the cap not being screwed or clamped to the jar. What holds the cap on the jar?

Could the flask and tube of the above exercise be used as a thermometer?

EXERCISE 8A

WHAT EFFECT IS PRODUCED UPON A VOLUME OF AIR BY A CHANGE IN ITS TEMPERATURE?

Materials. A toy balloon well inflated; a refrigerator (may be made by placing a piece of ice in a covered box or pail); one of the schoolroom radiators, hot-air register, or a heating stove.

Directions. Measure the circumference of the balloon accurately. Record the measurement. Place the balloon in the refrigerator for fifteen minutes, then quickly measure the same circumference again, and record. Then place the balloon above the radiator, register, or stove for fifteen minutes and measure in the same way again. Compare the three sets of measurements, and explain any differences.

Additional problems. Balloonists report that when a cloud remains between a balloon and the sun for a time, the balloon begins to descend, and ascends again when the sunshine falls upon the balloon. Explain.

Why do balloonists find it difficult to remain afloat at night?

EXERCISE 9

HOW ARE MERCURY THERMOMETERS USED?

Materials. Some common thermometers, either Fahrenheit (F.) or centigrade (C.).

Directions. The bright material in the thermometer is mercury (or quicksilver). See how far up the tube the mercury extends from the bulb. What happens if you warm the thermometer in the hands or by holding it above a stove? if you cool it? Do you get a quick result better by warming the stem or the bulb? Why? For what reason are thermometers always made with bulbs? What have you learned about the action of mercury when its temperature changes?

Additional problems. What is the temperature of your schoolroom at your desk? at the open window? near the heating apparatus?

If you have a thermometer the bulb of which can be placed in your mouth, determine the temperature of your body.

EXERCISE 10

WHAT IS THE RELATION BETWEEN THE FAHRENHEIT AND CENTIGRADE THERMOMETER SCALES?

Materials. Fahrenheit and centigrade thermometers; cups half filled with water.

Directions. Two persons may work together. They must have a centigrade and a Fahrenheit thermometer. Place both of these in water, and read both at the same time without removing them from the water. Record the readings in two parallel columns below, placing readings made at the same time opposite each other. After either warming or cooling the water, record the readings again. Do this for five or six different temperatures, recording your results. If possible, use a mixture of ice and water for one of the trials and hot water (almost boiling) for another.

The relation between the two scales can be determined by comparison of any two sets of readings. What is the number of divisions (degrees) on the Fahrenheit scale between your highest and lowest readings? What is the number of degrees on the centigrade scale between the corresponding readings? On which scale is the number of degrees between the two points the greater? A single degree on the centigrade scale is equivalent to how many degrees on the Fahrenheit?

Check your results by calculating from any other two sets of readings and by reference to your textbook.

	C.	F.
1		
2		
3		
4		
5		
6		

Additional problems. The temperature of the human body is usually about 98.6°F . What is the temperature in the centigrade scale?

The usual temperature of a good living room is about 20°C . What is the temperature in the Fahrenheit scale?

EXERCISE 10A

TO REPRESENT GRAPHICALLY THE RELATION OF CENTIGRADE AND FAHRENHEIT SCALES

Materials. A sheet of cross-section paper (paper ruled in two directions at right angles); the data from Exercise 10.

Directions. On the accompanying sheet of cross-section paper, the heavy horizontal lines are numbered to represent the Fahrenheit scale. The lowest heavy line represents 30° , the next one 40° , and so on to the top of the paper. Each light line thus represents one degree. Similarly the vertical lines represent the centigrade scale.

Place a point at the intersection of the line representing 212° F. with the line representing 100° C. This point represents the following relation:

$$212^{\circ} \text{ F.} = 100^{\circ} \text{ C.}$$

Locate another point to represent the following:

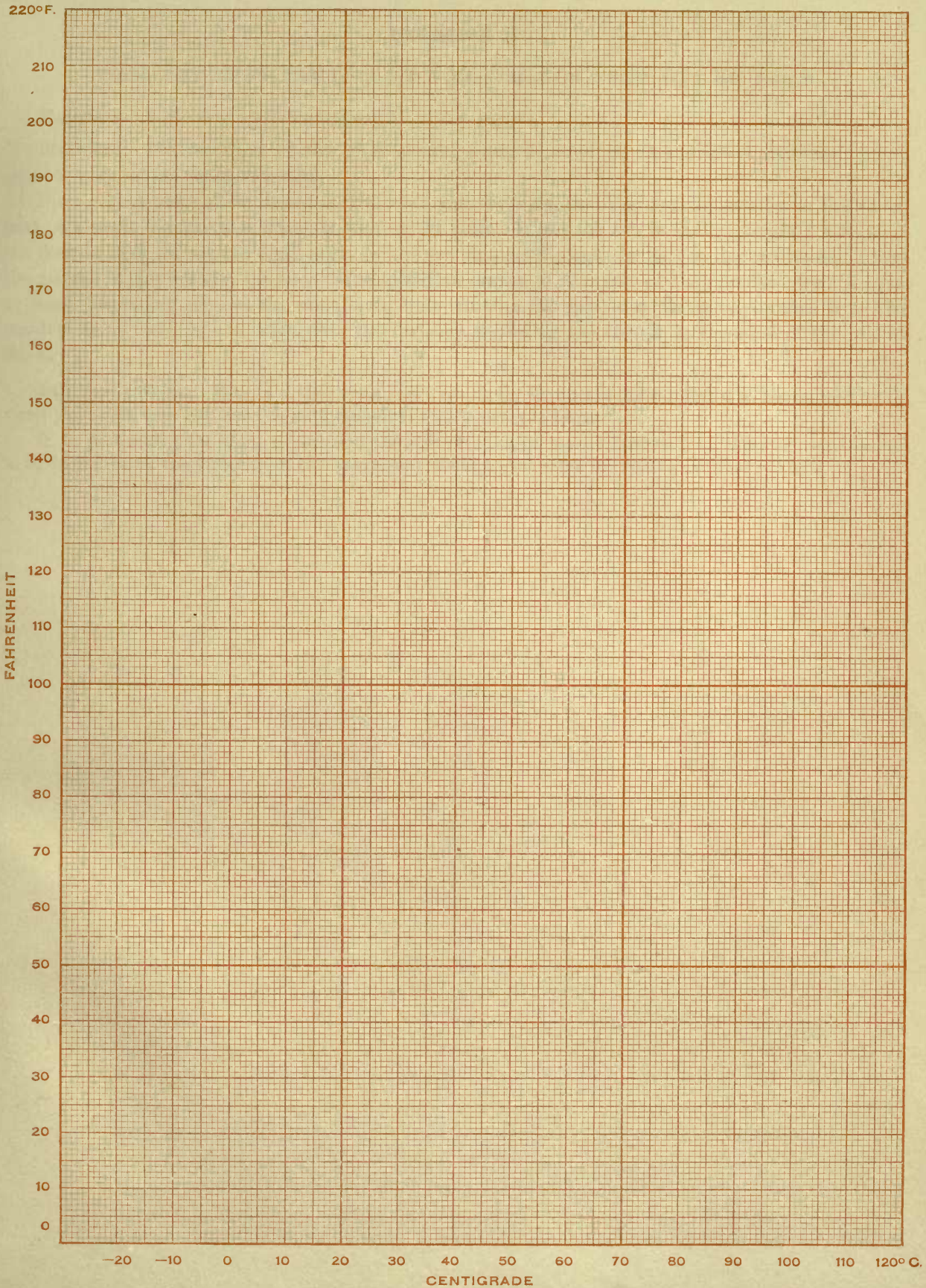
$$32^{\circ} \text{ F.} = 0^{\circ} \text{ C.}$$

Draw a straight line through these two points from one margin of the paper to the other. If accurately constructed, this line may be used as a means of transferring readings from one scale to the other. For instance, if the temperature of the room is 22° C., the Fahrenheit equivalent may be found as follows: Follow the 22° C. line upward to its intersection with the diagonal line. From the point of intersection follow the nearest horizontal line to the left side of the page and read off its value in the Fahrenheit scale. Reverse the process to change from Fahrenheit to centigrade.

Place on the page points to represent each pair of readings secured in the preceding exercise. The distances by which they are separated from the diagonal line are due to inaccuracies in your observations or in the thermometers.

Preserve this sheet and use it to change temperature readings from one scale to the other.

EXERCISE 10A



EXERCISE 11

DOES THE SUN'S POSITION AT NOON CHANGE FROM DAY TO DAY?

Materials. A piece of cardboard about 10 inches square.

Directions. The members of the class should work together on this exercise, but each pupil should write notes independently.

Place a large piece of cardboard with a hole about three eighths of an inch in diameter in the upper part of a south window and fasten it securely in place. When the sun is shining brightly notice on the floor or desk the spot of light made by the sun shining through the hole in the cardboard. Trace the position of the spot on the floor with a pencil or crayon at intervals of five minutes. On the next or some succeeding day, at the same hour, note whether the spot is at the same distance from the window as at first. If not, what does this indicate regarding the change in elevation of the sun in the sky?

Additional problems. Why is it that when you trace slowly the spot of light referred to above, your mark when you finish does not coincide with the mark with which you began?

If in performing the above experiment the spot of sunlight moved farther from the window or nearer to it, do you think the direction of this movement would be the same for twelve months? Why?

EXERCISE 12

TO DETERMINE THE DIFFERENT AREAS COVERED BY A BEAM OF LIGHT STRIKING THE SURFACE OF THE EARTH AT DIFFERENT ANGLES.

Materials. Some small blocks of wood 6 or 8 inches long and 1 inch square; a saw; a protractor.

Directions. Suppose that at one time of the year the sun's rays fall at an angle of 72.5° , and 25.5° at another time of the year. Cut one end of a block of wood at an angle of 72.5° and the other end of the block of wood at an angle of 25.5° . Then place each slanting end of this block on cross-section paper and trace the area covered by each of the ends. What are the corresponding areas covered by the two ends of the block? How many times larger is one than the other? Which is the larger? If a beam of light 1 inch square falls at an angle of 72.5° and another at 25.5° , which will have the greater heating effect on 1 square inch of surface? How many times greater? Why?

Additional problems. How are the facts of the above experiment related to the changes of seasonal temperatures?

When the lights of automobiles or bicycles approach a gateway or doorway, are the upright posts or the roadway between them the more brilliantly lighted? Why?

EXERCISE 12A

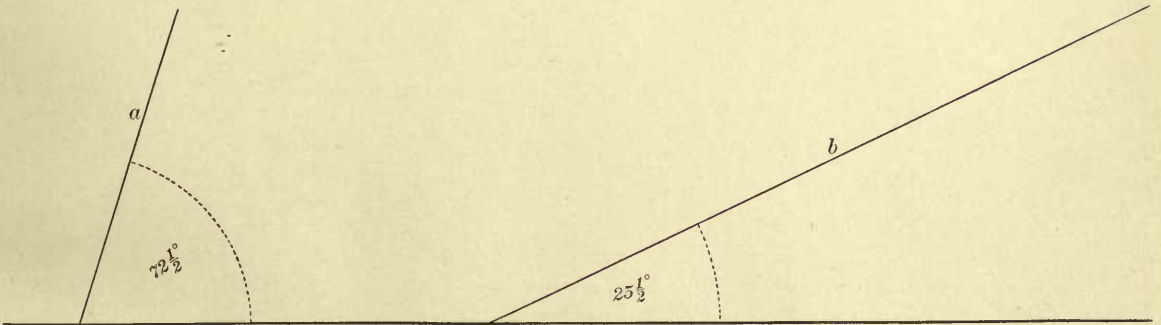
WHAT ARE THE DIFFERENT AREAS COVERED BY A BEAM OF LIGHT STRIKING THE SURFACE OF THE EARTH AT DIFFERENT ANGLES?

Materials. The representation of angles shown on this sheet.

Directions. Let the horizontal line in the figure below represent the surface of the earth. Line a is drawn so that it makes an angle of 72.5° as labeled, and line b makes an angle of 25.5° . These are approximately the angles which the sun's beams make in summer and winter, respectively, at a latitude of 41° . Draw a line parallel to line a at a distance of 2 centimeters from it. The length of the base line between the two intersections will then represent the length of a rectangular area covered by a beam of light 2 centimeters square. Taking this line as the length of the rectangle, complete the rectangle below the line, making it 2 centimeters wide. Calculate from its dimensions the number of square centimeters covered by a beam of light 2 centimeters square striking the earth's surface at an angle of 72.5° .

Draw a line parallel to line b and 2 centimeters from it; let the length of the base line between the two intersections represent the length of the area covered by a beam of light striking the earth at an angle of 25.5° . Using the width of the beam as 2 centimeters, complete the rectangle and calculate the area.

What do you conclude from the above work? How many times larger than the first area is the area covered by the beam striking the earth at an angle of 25.5° ? Why is it warmer in summer than in winter?



EXERCISE 13

TO MAKE A CHART WHICH WILL SHOW GRAPHICALLY THE LENGTH OF DAY AND NIGHT AT VARIOUS TIMES OF THE YEAR

Materials. Cross-section paper; a ruler; an almanac giving time of sunrise and sunset throughout the year.

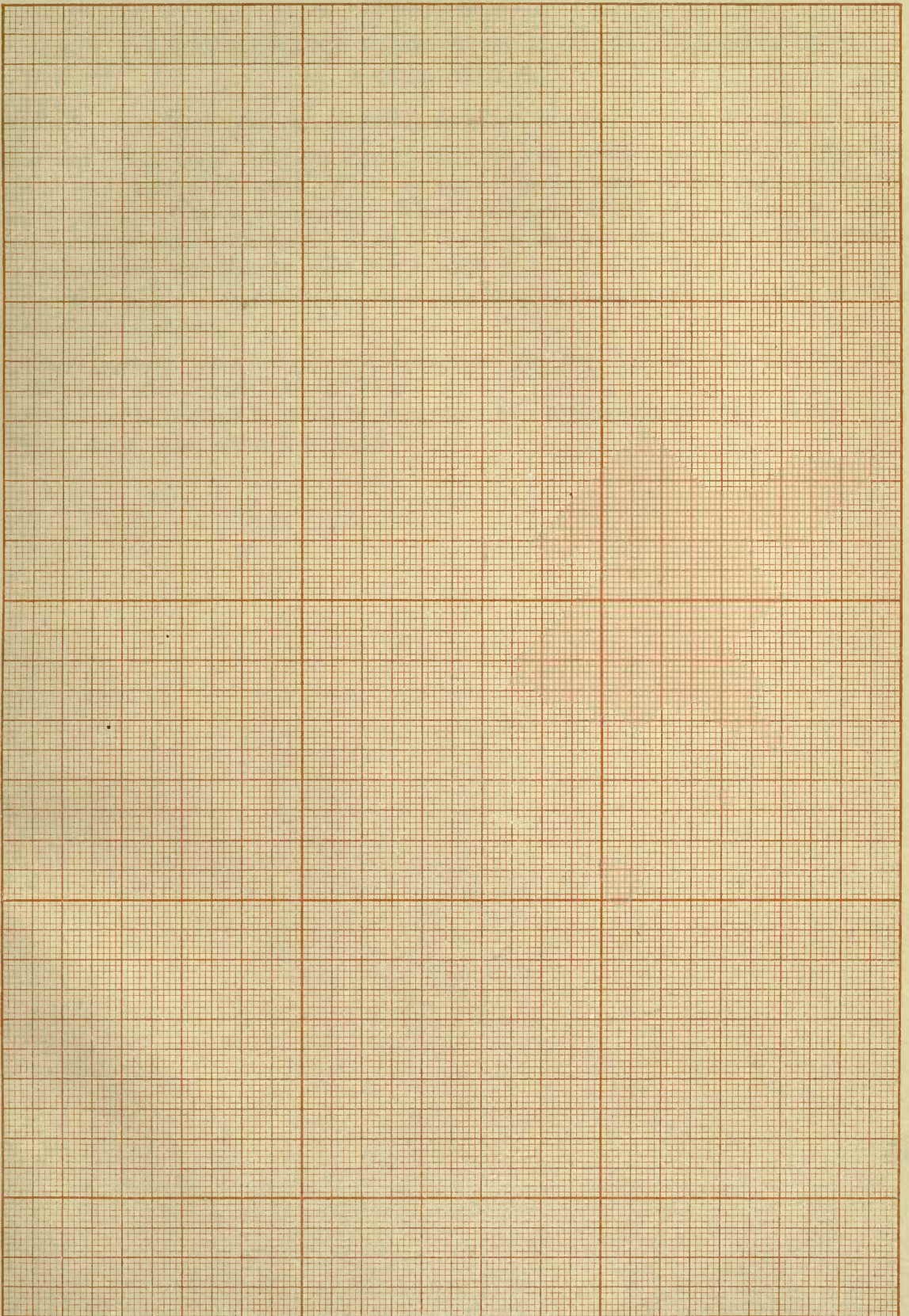
Directions. On the cross-section paper draw, in heavy black lines, as near as possible to the center of the page, a rectangle 13 centimeters high and 12 centimeters wide. This should follow the heavy centimeter lines. Let the vertical centimeter lines represent the even hours of the day from midnight to midnight, and they should be so labeled. The horizontal centimeter lines, except the top and bottom lines, will represent the first days of the twelve months. They should be labeled by writing the names of the months to the left of the rectangle, opposite the proper lines.

Find from an almanac the time of sunrise and sunset for the first day of each month, and mark the points which will correspond to these hours on the proper month lines. Ink those portions of the lines which represent night. When you have completed the chart examine it and state carefully what conclusions you may draw from it.

Can you give a reason for the change of hours of sunshine and darkness?

Additional problem. What is the length of the longest and of the shortest periods of daylight at the equator? at the tropic of Cancer or of Capricorn? at the arctic circle? at one of the poles?

EXERCISE 13



EXERCISE 14

WHAT HAPPENS TO WATER VAPOR WHEN IT COMES IN CONTACT WITH A COLD OBJECT ?

Materials. A polished metal cup, preferably aluminum, or a new tin cup ; ice ; salt.

Directions. Place water which has approximately the temperature of the room in a bright metal cup. Add ice or snow to the water. While the water is cooling watch for any deposit on the outer surface of the cup. What is the deposit ? Where did it come from ? Why is there not a similar deposit on other objects in the room ? If all of the air in the room were cooled to the temperature of the air in contact with the cup, what would happen ?

NOTE. If no deposit is obtained above, a lower temperature may be secured by adding a handful of salt to the ice and water mixture.

Additional problems. When a person who wears glasses goes from the cold out of doors into a warm room, the glasses often become "cloudy." Why ?

What causes the moisture to collect in summertime upon a glass or pitcher of ice water ?

What is dew ? What causes it to appear ?

EXERCISE 15

WHAT IS THE TEMPERATURE AT WHICH THE WATER VAPOR CONDENSES IN THE ROOM?

Materials. Same as in Exercise 14; the table on page 23, "Elements of General Science."

Directions. Use the same apparatus as used in Exercise 14. Record the temperature of the room. Stir the mixture of ice and water with a thermometer. Do not allow your breath to come in contact with the cup. When the first clouding of moisture appears, read the thermometer and record the temperature. Now remove the ice or snow and allow the cup to warm. When the last traces of moisture disappear, read the thermometer again and record. Make several trials, and average all readings. If your work has been accurate, this average reading is the approximate *dew point* (saturation temperature) of the water vapor in the room at the time when the experiment was performed.

What was the temperature of the room? Was the air in the room saturated at that time, or at what temperature would it have been saturated?

Additional problems. By reference to the table in the text find the weight of water vapor per cubic foot present in the room at the time of the experiment. This is the absolute humidity.

What is the weight of the water vapor in the entire room in which you are working?

EXERCISE 16

WHAT IS THE RELATIVE HUMIDITY IN THE ROOM?

Materials. Data from the preceding exercise; the table on page 23, "Elements of General Science."

Directions. From the preceding exercise (Additional problems) obtain the weight of water vapor per cubic foot of space in the room at the time the experiment was performed. Refer to the table to find out what weight of water vapor per cubic foot of space would have been present if the space had been saturated at the temperature observed at the time of the experiment. What percentage of the latter weight was the weight of water actually present? This was the relative humidity. Write a definition of the term *relative humidity*. State the difference between relative and absolute humidity.

Additional problems. When raindrops are forming and falling from the atmosphere, what is the relative humidity of the atmosphere?

It is sometimes said that the air in artificially heated rooms is like the air of a desert. By determining the relative humidity in the classroom on each of several days, see what basis there is for this statement. How can this condition be changed?

EXERCISE 17

WHAT IS THE RELATION BETWEEN AIR PRESSURE AND WIND?

Materials. A supply of daily weather maps, usually obtainable in sufficient quantity from the nearest United States Weather Bureau Station. By writing to the Weather Bureau, Washington, D.C., one may obtain a special bulletin entitled "Explanation of the Weather Map."

Directions. The teacher and students should study together a daily weather map and become familiar with the characters used to represent weather conditions. An explanation of these characters is printed on the map.

Select a map with a well-defined low-pressure area similar to the maps on page 31 of the "Elements of General Science." Study the wind direction as shown by the arrows around the low-pressure center. How many arrows indicate winds blowing (*a*) toward a lower pressure? (*b*) toward a higher pressure? (Arrows pointed as if to cross the isobar toward the lower pressure, though not at right angles, are to be counted in (*a*).) In what percentage of the whole number of cases studied does the wind blow from a high-pressure area to a low-pressure area?

What is your answer to the question of this exercise?

Additional problems. What conditions of air pressure over the United States would cause a warm wind from the south?

By study of weather maps for several successive days, see if you can determine the usual direction and average daily distance traveled by high and low pressures.

EXERCISE 18

IN WHAT DIRECTION DOES THE AIR MOVE AROUND THE CENTER OF A LOW-PRESSURE AREA?

Materials. Weather maps used in preceding exercise.

Directions. In the part of the map used in the preceding exercise, consider only those arrows included in (a), and determine: (1) how many of these arrows which indicate that the wind blows inward are there which cross the isobar perpendicularly; (2) how many arrows turn to their right of a line perpendicular to the isobar; (3) how many arrows turn to their left. What percentage of the arrows turn to their right? What does this result show about the general direction of the wind in a "low"? Make a diagram about 2 inches in diameter, showing the wind direction about a "low." Is this direction clockwise or counterclockwise?

Additional problem. If a "low" were to pass eastward across the country along a path lying north of you, what changes in wind direction would be experienced in your locality? What changes would there be if it passed south of you?

EXERCISE 19

WHAT EFFECT DOES THE ROTATION OF A GLOBE HAVE UPON THE DIRECTION OF MOTION OF OBJECTS ON ITS SURFACE?

Materials. A globe (preferably a slated globe) mounted so that it may be rotated readily; a pitcher or dish of water.

Directions. Place the globe in a position with its axis vertical. With the globe stationary pour a little water on its upper end, which may be marked "north pole." Note that the water flows to the other pole. Its path is like a meridian.

After drying the globe, rotate it in the direction in which the earth rotates—west to east. Pour a little water on the globe while rotating. When it has come to rest note the path which the water made. Is its path a meridian of the globe? Does it curve to its right or to its left on the upper half (northern hemisphere)? Does it curve to its right or its left on the lower half (southern hemisphere)?

If this holds good for the earth as well as for a small globe, what are your conclusions about the effect of the earth's rotation upon the direction of the winds? What have you seen upon the weather map which agrees or disagrees with this?

Additional problem. Can you determine what would be the prevailing direction of the wind if the earth did not rotate?

EXERCISE 20

IS AIR COMPRESSIBLE?

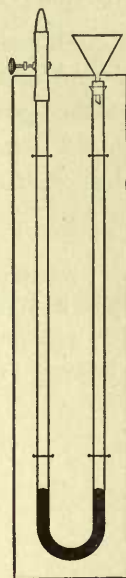
Materials. Glass tubing $\frac{1}{4}$ inch in diameter; a small glass funnel; rubber tubing to fit the glass tubing; pinch clamp; small wire; mercury.

Directions. Bend a 5-foot length of glass tubing to make a U-shaped tube with the arms about 4 inches apart. Wire this to a board or clamp it firmly to a ring stand in an upright position. To one end of the tube attach a small funnel by means of a rubber connection. Slowly pour in enough mercury to make a column about 2 inches high in each arm of the tube. To the other end of the tube attach a rubber connector closed with a pinch clamp. Measure the length of the air column in the closed arm of the tube. Now add mercury through the funnel and note the effect upon the volume of the air in the closed arm. Has any of the air escaped? How has it changed? When the open arm is nearly filled with mercury, slowly open the pinch clamp and listen for any evidence which will help you to answer the above questions.

Additional problems. When an automobile or bicycle tire is said to be full of air can more air be pumped into it?

What causes the loud report when an automobile tire bursts?

In a flask which is one fourth filled with water, insert a rubber stopper through which a glass tube extends almost to the bottom of the flask. The outer end of the tube should be drawn to a fine opening. Blow through the tube; note and explain what occurs when you stop blowing.



EXERCISE 21

DO GASES MIX WITH ONE ANOTHER?

Materials. The air of the schoolroom; any other gas, as illuminating gas or ammonia gas escaping from ammonia water.

Directions. With pupils seated at their desks, open the gas jet, noting the exact time of doing so. Allow each pupil to record the time when he first detects the illuminating gas. Does the illuminating gas reach all parts of the room? Have you any idea as to how it passed through the air? Open the windows, and after a few minutes see if you can detect the illuminating gas. What has occurred?

NOTE. Ammonia gas may be used instead of illuminating gas in the above experiment.

Additional problems. Is it a good plan to use a lighted match in hunting for a supposed leak in a gas pipe? Why?

If sufficient illuminating gas has escaped into a room so that the odor of the gas may readily be detected in all parts of the room, it is sometimes said, "The room is full of gas." Is there no air present?

EXERCISE 22

WILL GASES MIX WITH ONE ANOTHER IF THE LIGHTER GAS IS PLACED ABOVE
THE HEAVIER ONE?

Materials. Two wide-mouthed bottles (about 6- or 8-ounce bottles); illuminating gas; air.

Directions. Fill a wide-mouthed bottle with illuminating gas by collecting over water. Close the mouth of the bottle with a card and place the gas-filled bottle, mouth downward, upon a similar bottle filled with air. Withdraw the card. The air and the illuminating gas will thus be in contact in the necks of the bottles with the lighter of the two gases above.

After fifteen or twenty minutes test each bottle with a flame to discover whether the illuminating gas has gone down into the lower bottle, or air from the lower bottle has gone up. How do you explain the results?

Additional problem. Why are not the gases of the air in separate layers? Would they be if there were no winds?

EXERCISE 22A

DO LIQUIDS DIFFUSE?

Materials. A tall, narrow glass cylinder or jar; litmus solution; a long glass funnel tube; sulphuric acid.

Directions. Fill the glass cylinder or jar with water colored blue with litmus, to which a drop of ammonia has been added. Insert a long glass funnel tube, and pour into it two or three drops of sulphuric acid. Allow the jar to stand *undisturbed* with the funnel in position for a few days. Since the acid is nearly twice as heavy as water it will soon find its way to the bottom of the jar. The acid turns blue litmus to a red color. Note whether there is any indication that the heavier acid goes up through the water.

In case acid and litmus are not at hand, fill the jar with clear water and drop into it several crystals of blue vitriol. A heavy blue solution will be formed at the bottom. Observe as above. This should be set up a week or more before you are ready to draw conclusions.

Additional problem. If sugar is placed in coffee or tea and the liquid is not stirred will the sugar sweeten it? Why?

EXERCISE 23

DOES A LIQUID FILL ALL THE SPACE WHICH IT APPEARS TO FILL?

Materials. A glass tube 18 inches long and about $\frac{3}{8}$ inch in diameter; two cork stoppers to fit the tube; alcohol.

Directions. Into the tube, which is stoppered at one end, pour water until it is half full. Inclining the tube, carefully and slowly add enough alcohol to completely fill the tube. Stopper the open end of the tube and invert it several times, until the liquids are completely mixed. Now bring to original upright position. Is the tube now completely filled with the liquids? How can you account for the decrease in volume of the liquids?

EXERCISE 24

WHAT ARE THE PARTS OF A FLAME?

Materials. A wax, tallow, or paraffin candle; matches.

Directions. Light the candle. Find and describe three layers, or zones, in the candle flame. The inner zone is dark; the middle zone is bright; and the outer zone is pale blue and forms only a thin layer over the surface of the flame.

Make a diagram of a flame showing the principal facts. This should be of natural size or larger, and may be colored with crayons or water colors. Label the parts.

Additional problem. Does an illuminating gas flame show the same parts as the candle flame? Does the Bunsen flame? Does the kerosene flame?

EXERCISE 25

DO THE PARTS OF THE FLAME DIFFER IN HEAT?

Materials. Flame of a candle; white paper.

Directions. Hold a piece of white paper stretched horizontally between the two hands, and quickly thrust it into the flame in such a position that the center of the paper is just above the wick. Hold it there until the paper begins to char, and then quickly remove it before it catches fire.

Examine the mark which the flame has made upon the paper, and state your conclusion regarding the relative heat of the inner and middle zones. Do you think that there is any burning taking place in the inner zone? If not too much charred, the paper may be pasted in your notebook as an illustration.

Additional problems. Hold a match or a straw across the flame for a moment; then remove and see where the match or straw is burned.

See if you can quickly put a match head into the central part of a Bunsen flame and hold it there for a moment without lighting it.

EXERCISE 26

OF WHAT IS THE CENTRAL PART OF THE FLAME COMPOSED?

Materials. Glass tubing; candle flame; holding clamp or wire; matches.

Directions. Prepare a glass tube several inches in length by drawing out one end so as to secure a small opening. With a metal clamp or wire hold it nearly vertical, with the large end down, and place the large end in the center of the candle flame. Bring a lighted match to the tip of the tube and observe what happens.

After completing this part of the experiment, remove the tube from the flame and allow it to cool. What is the nature of the material which condenses and hardens on the inside of the tube?

What are your conclusions, and the reasons for them?

NOTE. This exercise may be performed by the teacher in a more striking manner if the tube used is from 8 to 10 inches long and $\frac{1}{4}$ inch in diameter. It should be clamped firmly in position at an inclination of about 45° , and its whole length must be heated by passing a flame back and forth along the tube to prevent cooling and condensation of the gas before it reaches the tip of the tube.

Additional problems. In the above experiment why is it necessary to keep the long tube warm?

When the gas which was discovered at the center of the flame has passed through the bright zone, is it the same kind of gas?

With an inverted funnel gather the escaping gas, and try to light it.

EXERCISE 27

A PRODUCT OF THE BURNING CANDLE

Materials. A candle (an alcohol lamp or Bunsen burner may be used); a piece of metal.

Directions. Hold a cold metallic object in the flame or just above its tip. Remove the object in a few moments before it becomes warmed. What, apparently, is the substance, other than soot, which has collected on the surface of the object?

Additional problems. If an alcohol lamp or a Bunsen burner is available, repeat the experiment, using these flames. Compare results.

Hold a dry drinking glass over a flame to see if the same results are shown.

When a kerosene lamp is first lighted what is the source of the water which collects on the inside of the lamp chimney?

When a kettle of cold water is placed over the flame of a gas stove, drops of water often collect on the bottom of the kettle. Explain.

EXERCISE 28

IS WATER A SIMPLE SUBSTANCE, OR IS IT COMPOSED OF MORE THAN ONE SIMPLE SUBSTANCE?

Materials. A bottle with the bottom removed; a two-holed stopper fitting the bottle, holes in the stopper permitting the passage of platinum wires or carbons through them; copper wire; three or more dry cells; sulphuric acid; two test tubes.

Directions. This experiment is best performed by the teacher. It is most conveniently done by the aid of a standard electrolysis apparatus such as is furnished by the various laboratory supply firms. If no such apparatus is at hand, the one shown in the diagram may be prepared.

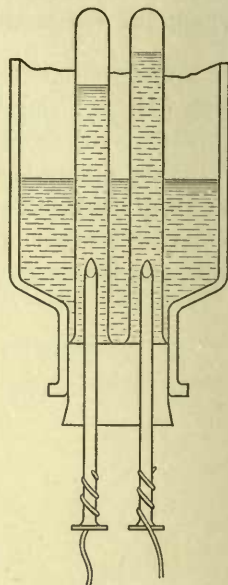
Partly fill the jar with a solution made by adding one part of concentrated sulphuric acid to sixty parts of water.¹ Fill the two test tubes with the same solution and invert them over the ends of the wires without admitting any air. Attach to the free ends of the wires a battery of three or more dry cells connected in series, and observe what happens. Allow the gases that are given off to collect in the test tubes. Note the relative volumes of the contents of the two tubes. When the tube containing the greater volume of gas is nearly full, disconnect the batteries and remove this tube, placing a finger over the open end of the tube and keeping the mouth of the tube downward. Bring a lighted match to the mouth of the tube and note the popping noise and the pale-blue color of the flame. The gas which was in this tube was hydrogen.

Remove the second tube carefully and test the collected gas by thrusting a glowing, not flaming, pine splinter into the mouth of the tube. Observe what happens. This gas is oxygen.

Considering that the amount of sulphuric acid is not lessened even if the current is allowed to pass for a long time and therefore cannot be the source of either gas collected, write your notes and answer to the question of this exercise.

Notes. If this experiment is performed in a laboratory fitted with a direct-current electric-lighting circuit, the proper current may be obtained by passing it through one or more sixteen-candle-power lamps. If more than one is used, they should be arranged in parallel.

If wire nails are used instead of platinum wires or carbons, it must be kept in mind that the acid will probably act upon the iron, and the results will be less satisfactory.



¹ Always add the acid to the water, never in the reverse order.

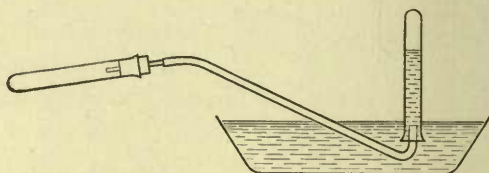
EXERCISE 29

WHAT IS THE NATURE OF OXYGEN — THE LESS ABUNDANT GAS FORMED IN THE DECOMPOSITION OF WATER?

Materials. Some test tubes; potassium chlorate; a short piece of glass tubing; a piece of rubber tubing; pine splints; a few wide-mouthed bottles; some glass plates about 2 inches square; sulphur; iron picture wire; a candle.

Directions. This experiment may be performed by the teacher or by the pupils working in groups of two.

Place enough potassium chlorate in a test tube to make a layer about three fourths of an inch deep, and arrange a delivery tube to collect over water the gas which is formed when the potassium chlorate is heated. Fill a test tube with the gas, after having allowed the gas to form from the chlorate long enough to expel the air from the generator.



a. Note the odor and color of the gas. (The gas should first be washed by shaking it with some water in a test tube sealed with the thumb.) Now take an ordinary match or a pine splint which is glowing, but not flaming, and thrust it into the tube. Does the match burn brighter?

b. Try to light the gas with a flaming match to see if it will burn.

c. Test the gas to see if it is lighter or heavier than air by holding a glowing splint above a tube of oxygen, and then invert the tube and hold the glowing splint below the tube. What is the result?

d. Fill a bottle with the gas, collecting it over water as illustrated. Unbraid the end of a 10-inch length of ordinary picture wire, heat it for a moment, and dip it into some sulphur or paraffin. Ignite the sulphur or paraffin and thrust it into the bottle of gas, and observe what happens.

e. By means of a wire, lower a short, burning candle into a second bottle of the gas. What occurs?

Additional problems. Does oxygen support combustion of a piece of wood better than air does?

Would the iron of iron-framed buildings be fireproof if the air were composed entirely of oxygen?

Would it be of advantage for the blacksmith to use oxygen instead of air in the bellows to blow the fire with which he heats his iron?

EXERCISE 30

WHAT IS THE NATURE OF HYDROGEN — THE MORE ABUNDANT GAS FORMED IN THE DECOMPOSITION OF WATER ?

Materials. An apparatus like that shown in Fig. 36, page 64, of "Elements of General Science"; some mossy or granulated zinc; concentrated hydrochloric or sulphuric acid; test tubes; wide-mouthed bottles; pine splints.

Directions. This experiment should be performed by the teacher. Since a mixture of hydrogen and air is explosive, a flame should never be brought near the generator by one who is inexperienced in handling the gas.

Put into the generator bottle a small handful of fragments of zinc (granulated, mossy, or sheet zinc, or iron). Place the stopper in the mouth of the bottle. Add enough water through the funnel tube to cover the zinc and the end of the funnel tube. Now add about 10 cubic centimeters of concentrated hydrochloric or sulphuric acid. Observe what happens. Do not collect the gas which first escapes from the tube. This is air or a mixture of air and hydrogen. Now collect two bottles of the gas as in Exercise 29; cover these with glass plates and set aside for the tests *c* and *d* below. More acid may be added if necessary. Also collect two test tubes of the gas for tests *a* and *b*.

a. Hold a tube of the gas mouth downward for a minute, and then bring a flame to the mouth of the tube. What occurs ?

b. Hold a second tube of the gas mouth upward for one minute, and then bring a lighted match near the mouth of the tube. Does anything happen ? What do the results of *a* and *b* show relative to the weight of the gas in comparison with that of the air ?

c. Bring a flame to the mouth of a bottle of the gas and see if the gas burns. Note the color of the flame.

d. Thrust a long flaming splint into the second bottle of the gas, the bottle having been inverted, and note the result. Does the gas support the combustion of the splint ? Hold the splint in the bottle and see if it will be relighted by the burning gas.

Additional problems. Soap bubbles may be made by use of hydrogen gas if the gas is first purified by being passed through a solution of caustic soda.

Why is hydrogen used in dirigible balloons ?

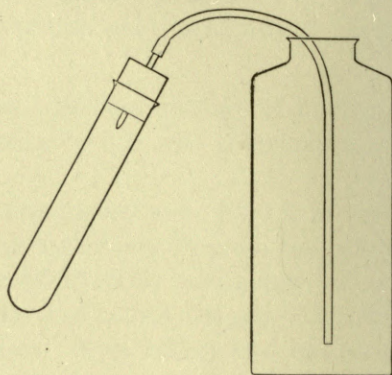
EXERCISE 30A

CAN WATER BE FORMED BY BURNING HYDROGEN IN OXYGEN?

Materials. Apparatus used in Exercise 29, also that used in Exercise 30; clean, dry bottle; a short glass tube drawn to a small opening.

Directions. This exercise should be performed by the teacher.

Fill a clean dry bottle with oxygen (see figure). Now generate hydrogen with the apparatus used in Exercise 30. Insert a small glass tube drawn to a rather small opening into the rubber delivery tube. After the hydrogen has been forming for a few minutes, catch a test tube of the gas by holding the tube in an inverted position and bringing the delivery tube into the mouth of the test tube. Remove the test tube from the delivery tube, and holding it with the mouth downward, bring a lighted match to the mouth of the tube. If an explosion occurs, catch another tube of the gas and test. When the gas is free from air and burns with a noiseless flame, light the gas issuing from the tip of the delivery tube and lower the hydrogen flame into the clean bottle. A cover for the bottle may be made by thrusting the glass tube through a piece of cardboard. Allow the hydrogen to burn until it is extinguished. What does the deposit on the inside of the bottle appear to be?



Additional problems. What does this exercise prove about the composition of water?

How do you explain the formation of water when a candle burns?

EXERCISE 31

WHAT IS THE GAS GIVEN OFF BY A BURNING CANDLE?

Materials. A candle ; a piece of wire ; a clean bottle ; limewater (prepared by dissolving slaked lime in water and using the clear water that may be poured off).

Directions. Suspend a short lighted candle by means of a wire and lower it into a clean bottle or glass. Cover the container as completely as possible and observe what happens. Why does the candle cease to burn ? Now remove the candle, quickly pour about 10 cubic centimeters of limewater into the bottle, and, with a glass cover on the bottle, shake the contents vigorously. Observe what takes place. Limewater is clouded by carbon dioxide. This cloudiness is due to a new compound which settles at the bottom. The gas which forms a white compound with limewater is called carbon dioxide.

Additional problems. Leave a wide dish of limewater exposed for 24 hours. What occurs ? Explain.

By use of a glass tube blow your breath into a bottle of limewater, and explain what occurs.

Hold an empty bottle over a gas flame ; then pour limewater into the bottle. Explain results.

EXERCISE 32

WHAT IS THE COMPOSITION OF CARBON DIOXIDE?

Materials. Bottle; oxygen generator; charcoal; forceps; limewater.

Directions. Fill a bottle with oxygen. Heat a piece of charcoal (carbon) in a flame, holding it with a forceps, until it is red-hot, and then thrust it into the bottle of oxygen. Observe what happens. Hold it in the bottle until it no longer glows and then remove it. Test the gas in the bottle by lowering a flaming match into it. What do you think it is? Now add about 10 cubic centimeters of limewater and shake the bottle. What does the result prove the gas to be? What does this prove about the composition of the gas given off by a candle? Where do the carbon and the oxygen come from?

Additional problems. If paraffin wax is composed of carbon and hydrogen only, how do you explain the formation of carbon dioxide and water when the candle burns?

Why is the candle flame hottest in the thin blue layer on the outside of the flame?

Why does not the gas burn in the inner cone of the flame?

EXERCISE 33

WHAT ARE SOME OF THE PROPERTIES OF CARBON DIOXIDE?

Materials. Test tubes; hydrochloric acid; chips of marble; apparatus used in Exercise 30; bottles; candle.

Directions. Generate several test tubes of carbon dioxide by the action of hydrochloric acid on marble, using the apparatus shown on page 64 of "Elements of General Science." This may be done by groups of students working together. Test the gas by use of limewater to see if it is carbon dioxide.

a. What is the color and odor of the gas? (If the gas is not washed by shaking with water, the odor of hydrochloric acid will be detected.)

b. Is it lighter or heavier than air? To determine this, hold a flaming match over a bottle of the gas and then invert the bottle over the flame of the match. What does the result show?

c. Does the gas burn? Does it support combustion?

d. Fill a bottle with carbon dioxide. In another bottle place a burning candle. Then pour the carbon dioxide upon the candle. Explain results.

Additional problems. Weigh a beaker upon a balance; then leave the exact weights used upon the scale-pan. Pour carbon dioxide into the beaker and replace the beaker upon the balance. Explain any difference in weight.

Fill a large container with carbon dioxide; then pour the gas down an inclined trough which holds several very short burning candles. What happens? Why?

EXERCISE 34

CAN THE GREEN COLORING MATTER BE REMOVED FROM LEAVES?

Materials. Some fresh green leaves, those of the geranium and nasturtium; a beaker or metal dish in which to boil water; a smaller beaker which may be placed within the preceding one; alcohol.

Directions. Since the common tests for the presence of food materials depend upon color changes, it is necessary to bleach the leaf before applying a test such as is mentioned in the following experiments. It will often be better for the teacher to perform the experiment, but the results should be seen and handled by each pupil.

Dip each leaf in boiling water once or twice, keeping it in the water only long enough to kill it, as indicated by its becoming limp as if wilted. Place all the leaves in a beaker or other convenient container with enough alcohol to cover them. Heat the alcohol to about 75°C . for ten minutes. Since alcohol is inflammable, the heating is best accomplished by setting the vessel containing the alcohol in the vessel containing hot water, using the principle of the double boiler.

At the end of this ten minutes' heating, remove the leaves and rinse in water. Examine both leaves and alcohol. What has happened to the green coloring material of the leaves? This coloring material is called chlorophyll.

NOTE. The experiment can be performed without the use of heat, but the operation takes much longer in this case. Pupils may perform the experiment at home by immersing leaves in cold alcohol for 24 hours or longer. In this case keep the dish or bottle tightly closed to prevent evaporation of alcohol.

Wood alcohol has the same effect upon the chlorophyll as common or grain alcohol, but because of the poisonous nature of wood-alcohol fumes it is better to use grain alcohol.

Additional problems. How do you account for the peculiar appearance of shoots and leaves of plants such as potatoes, asparagus, etc., which have grown entirely in darkness?

Plant mustard seeds, or those of wheat, oats, and beans, in darkness, and remove them to the light when the plants are an inch tall. What color changes follow removal to the light?

Evaporate the alcohol in which chlorophyll was dissolved, evaporating it slowly by allowing the dish to stand in a draft. What is left in the dish?

EXERCISE 35

IS THERE A FOOD MATERIAL IN THE LEAF, AND DOES IT HAVE ANY RELATION TO CHLOROPHYLL?

Materials. A fresh white potato or some commercial starch; plants with white-spotted or partially green leaves, as some kinds of geraniums; dilute solution of iodine (tincture of iodine); the apparatus and materials used in the preceding exercise.

Directions. Cut a thin slice from the potato or spread out some commercial starch on a glass plate, and place upon it a drop of the dilute iodine solution. What is the color of starch when treated with this solution?

Select a number of leaves which have been exposed to the sun for several hours. Remove them from the plant. Note carefully and make sketches to show the size and location of the light spots of the leaf. Remove the chlorophyll from the leaves as in the preceding experiment.

When the chlorophyll has been removed from the leaves, take them from the alcohol, place them in a dish, and cover them with some of the dilute iodine solution.

In five or ten minutes examine the leaves. What do the results show? Examine the variegated leaves to determine whether there is any relation between the location of the starch and the location of the chlorophyll.

Additional problems. Can non-chlorophyll-bearing plants make food material?

Do plant stems contain chlorophyll?

Where is the chlorophyll in a cactus plant?

EXERCISE 36

IN WHAT PART OF THE LEAF IS THE CHLOROPHYLL?

Materials. Thin leaves, as those of moss, water weed (*Elodea*), pondweed (*Potamogeton*); one or more compound microscopes, or a microprojection apparatus; glass slides and cover glasses.

Directions. If a sufficient number of compound microscopes are to be had, each pupil may perform this experiment independently, but if there is only one microscope, the teacher should arrange a demonstration exercise. If the school possesses a microprojection apparatus, the specimen may be shown to the entire class at once.

Mount a very thin leaf in a drop of water on a glass slide, cover with the cover glass, and examine first with the low power and then with the high power of the microscope.

Does the chlorophyll color the leaf evenly? Can you distinguish the rounded bodies which are called chloroplasts? Is there any chlorophyll in the leaf which is not in the chloroplasts? Groups of these chloroplasts and other substances are inclosed within transparent, thin walls. These are the cell walls, and the spaces inclosed by them contain not only the chloroplasts but also the other living material of the cell. The living material is so transparent that it will probably not be seen.

Observe and describe carefully all that has been done.

Additional problem. Is the upper or lower surface of ordinary leaves more green? Is this true of all leaves?

EXERCISE 37

WHAT IS THE NATURE AND USE OF THE OUTER COVERING OF THE LEAF?

Materials. Some rather thick leaves (life plant (*Bryophyllum*) and live-forever are good, as are most species of lily, iris, and amaryllis).

Directions. Peel off a bit of the "skin" (epidermis) from each surface of the leaf, noting especially its thinness and transparency. If you cannot peel off the epidermis, try to scrape away one covering and all the other material of the leaf from a small area, leaving only the other epidermis. Write notes describing the epidermis.

Describe the kind of material that fills the space between the upper and the lower epidermis. It is called the mesophyll, meaning "middle leaf." Is it easily injured? Let a piece of the leaf, with epidermis removed, lie on the desk for a while, and note the effect on the mesophyll.

Explain the use of the epidermis with proofs secured from your study. See pages 71-74, "Elements of General Science," for a discussion of the internal structure of the leaf.

Additional problems. Examine a piece of the epidermis, mounted in water, under the microscope. Note the shape of the cells. Are they all of one kind? Can you locate the crescent-shaped cells (guard cells) with the slit-like opening between them? These, with the openings, are the so-called "breathing pores" or stomata. Do the guard cells have chloroplasts? Are the guard cells of the same shape in all stomata? in stomata of different leaves? at different times of day?

Study a cross section of a leaf.

EXERCISE 38

IS THERE A WASTE PRODUCT GIVEN OFF DURING FOOD MANUFACTURE?

Materials. An aquarium containing some submerged water plants (the following may be grown in such aquaria: water weed (*Elodea*), the pondweeds (*Potamogeton*), water milfoil (*Myriophyllum*), and hornwort (*Ceratophyllum*), these being common in most parts of the country).

Directions. Place the aquarium with submerged water plants in the sunlight and examine it after fifteen or twenty minutes. Under these conditions the manufacture of foods should be going on in the green parts of the plants. Observe whether a gas is given off from the plants. Darken the aquarium and after a little while examine again to see whether the gas is still coming off from the plants.

Almost any kind of submerged water plant will answer for this experiment. During the growing season they can be obtained in most bodies of shallow and rather quiet water, such as the margins of lakes and rivers. They grow readily in aquaria. Every laboratory should carry several such aquaria through the winter.

Additional problems. In drinking troughs for domestic animals where water stands for a long time, small, threadlike green plants (the pond scums) often are found growing. Observe these plants when the sun is shining upon them. What do you think is the origin of the bubbles seen among these plants and arising from them? Similar conditions may be observed when pond scums are found floating at the top of the water of ponds and sluggish streams.

Heat water until the air in it has been driven to the surface. Cool the water as rapidly as possible until it is at air temperature. Place water plants in this water and place in the light. Are gas bubbles thrown off by the plants in this case? By means of a glass or rubber tube blow your breath into the water at the bottom for a few minutes. Does this seem to affect the quantity of gas bubbles later produced by the plants?

An interesting modification of the experiment of this exercise is possible if an arc-light stereopticon is available. In this case a sprig of one of these plants may be placed in water in one of the thin-glass tanks which are supplied for the purpose, and inserted in place of the slide. The light will be sufficiently intense to enable the plant to carry on photosynthesis, and bubbles will be seen to rise from the plant.

EXERCISE 39

WHAT IS THE NATURE OF THE GAS GIVEN OFF DURING CHLOROPHYLL WORK ?

Materials. Deep glass jar or aquarium ; large glass funnel ; test tube.

Directions. Collect some of the gas which arises from the plants under the conditions of Exercise 38. Test it in the different ways which you used in earlier experiments, to find out if it is one of the gases with which you are familiar.

The collection may best be done in the following manner: Put the plants under an inverted glass funnel in a deep jar. The funnel must be wholly submerged. Fill a test tube with water and invert it over the stem of the funnel. The bubbles which arise from the plants will pass up into the test tube, which may be removed for the tests when a sufficient quantity has been collected. To collect a sufficient quantity of the gas within a reasonable time it will be necessary to use a large quantity of plants and therefore a large funnel.

Additional problems. In what sense is it true that a green plant is an oxygen-producing machine ?

Of what significance is it to other living things to have large quantities of oxygen set free by green plants ?

Can animals contribute to the supply of free oxygen in the air ? Can mushrooms and molds ?

EXERCISE 40

HOW DOES A DEPENDENT PLANT LIVE?

Materials. A piece of bread or stale banana; a glass dish with cover; a magnifying glass.

Directions. Moisten a piece of bread slightly and expose it to the dust of a room for an hour; then cover it to prevent drying, and put it in a warm place. If the banana is used it is treated in the same way, except that it should not be moistened. Observe daily. One or more varieties of mold will appear within four or five days. Describe the growth of the mold and its appearance. From what source do you think it secures its nourishment? Do you think it manufactures carbohydrates?

Study with a magnifier or microscope to learn more about its structure. Note particularly the dustlike spores and the way in which they occur on the plant. If satisfactory observations of the mold are secured under magnification, make sketches showing the structures.

These spores are the reproductive bodies. How well are they adapted for distribution by the air?

Additional problems. Can you explain how the mold came to grow on the bread without anyone's purposely planting it?

If bread or fruit which is entirely mold-free is kept tightly closed in a mold-free container, will mold develop on the bread?

What other kinds of plants do you know which are dependent in the same sense that mold is?

In what ways is the life of rusts and smuts like that of mold? How different?

EXERCISE 41

WHAT IS THE NATURE OF THE YEAST PLANT?

Materials. Cake of compressed yeast; molasses or sugar; bottles; rubber and glass tubing; limewater.

Directions. Dissolve some sugar or molasses in water. Do not make the solution stronger than 10 per cent. Add a little yeast which has been thoroughly mixed with water.

From day to day note the bubbles which rise and the increasing amount of sediment and scum.

Place some of the solution and sediment in a bottle and close the bottle with a one-holed rubber stopper through which a glass tube has been passed. Attach a rubber tube and collect some of the gas which escapes, as you did in Exercise 29. It may take a day or more to fill a bottle. Test the collected gas with a flame, with limewater, and by any other means that you think of, to find out whether it is one of the gases with which you are familiar.

When you have discovered what gas it is that is coming from the sugar solution, try to explain how it may have been produced.

Additional problems. If a compound microscope is available, examine the sediment to see what the yeast plant is. How are new yeast plants formed?

How does yeast cause bread to "rise"?

EXERCISE 42

WHAT EFFECT HAS HEAT UPON THE YEAST PLANT AND FERMENTATION ?

Materials. Test tube or flask ; cotton batting ; the sugar solution used in the preceding exercise.

Directions. Stir very thoroughly the fermenting sugar solution in the generator used in the preceding experiment, and pour some of it into a flask or a test tube. Heat it to boiling temperature for a few minutes, and then plug the flask or tube with a cotton stopper. Allow the tube to stand for a day, and observe if fermentation continues. What is the effect of heat upon yeast plants ? To what practical use could you put the information gained in this exercise ?

Additional problems. How is it that cider or sugar solutions ferment even when no yeasts have been purposely placed in them ?

Why was a cotton stopper used in the above experiment instead of a cork or rubber stopper ? Why use any stopper ?

Does fermentation continue in bread after the bread is baked ?

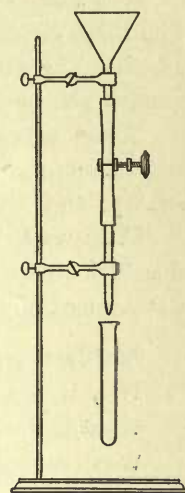
EXERCISE 43

HOW DO BACTERIA ACT ON MILK, AND HOW MAY MILK BE PRESERVED FROM SUCH ACTION ?

Materials. Test tubes; cotton; skim milk; funnel; rubber and glass tubing; pinch clamp; wire basket; formalin; steam sterilizer (may be made with common materials as directed below); gummed labels.

Directions. Pupils should work in groups of two. Each group should be provided with six clean, dry test tubes and enough cotton to make plugs for the tubes. Place about 1 inch of skim milk in each test tube. Avoid getting milk on the mouth or upper inner part of the tube by using a large funnel fitted with a rubber connecter with a pinch clamp; the end of the rubber tube holds a glass tube drawn out to a small opening. Pour the milk into the funnel. The proper volume of milk may be allowed to enter the tube by controlling the pinch clamp. Immediately plug the test tubes with cotton. Set one tube in the rack and with a gummed label mark it "1."

Place the other five tubes in a wire basket and treat as described below. Place the tubes in a steam sterilizer. Sterilizers such as are often used for sterilizing milk for small children will be as satisfactory as the laboratory type. Keep the water in



	TUBE 1	TUBE 2	TUBE 3	TUBE 4	TUBE 5	TUBE 6
1st day		Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes
2d day		Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes	Sterilized.....minutes
3d day		Sterilized.....minutes	Sterilized ....min. 1 drop sour milk added	Sterilized ....min. 1 drop sour milk 1 drop formalin	Sterilized ....min. 10 drops drink- ing water added	Sterilized ....min. Plug removed 30 minutes
4th day						
5th day						
6th day						
7th day						
8th day						
9th day						
10th day						

EXERCISE 43 (Continued)

the sterilizer boiling for twenty minutes. Allow the tubes to cool, repeat the treatment twenty-four hours later, and preferably a third time one day later. If no sterilizer is to be had, set the tubes in a vessel of water in such position that they are half immersed in the water but are not in contact with the bottom of the vessel. Boil as directed above.

It is supposed that the heating will have killed any living things in the tubes, as in Exercise 42. The three sterilizations are intended to make sure of this. Set aside one of the sterilized tubes to see whether any changes will occur in it. Label it "2." Do not at any time during the experiment remove the cotton plug. Label the remaining tubes "3," "4," "5," "6."

When tubes "3" to "6" have cooled from the last sterilization, treat them as indicated in the tabulation above. Keep a daily record of observations for at least a week. Curdling, becoming watery, and alterations of color are changes which are easily seen.

Make each tube the basis of a statement regarding what you have learned from it. Your notes should include, in addition to the statement of the method of preparing and sterilizing the tubes and a statement of the conclusions, a tabular presentation of the records of the experiments.

Additional problems. Is there objection to the use of formalin in preserving milk?

Why is absolute cleanliness necessary in handling milk? How can such cleanliness be secured?

What is the importance to the public of having great care observed in handling milk?

When canning fruit, should the fruit be allowed to cool before the lids are placed on the cans? Why?

EXERCISE 44

WHAT CHANGES IN VOLUME TAKE PLACE WHEN WATER FREEZES ?

Materials. A short test tube or a small vial without a constricted neck; a two-holed rubber stopper to fit the test tube or vial; a thermometer; a glass tube about one foot in length and fitting tightly one of the holes in the stopper; ice or snow; salt.

Directions. Fill the test tube or vial with water and close it with a two-holed rubber stopper in which are a glass tube and a thermometer. The tube should not extend below the lower surface of the stopper. Push the stopper down until the glass tube is about half full of water. Fasten on the back of the glass tube a paper centimeter scale cut from cross-section paper.

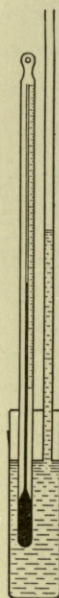
Set the test tube or vial in a beaker or cup and surround it with a freezing mixture made by adding ice or snow to a heavy brine solution.

Watch the tube from the beginning, and record the changes in height of water in the tube. Note the height of the column for each degree of change of temperature, and record each measurement with the reading of the thermometer at the same time.

After you have recorded your observations, try to make conclusions, with proof, on the following points: What changes in volume take place when water freezes? At what temperature does a given amount of water occupy the least volume? When is water heaviest per cubic inch? When lightest? Compare your results with results known to be correct, which will be given by the teacher or in the textbook.

Additional problems. Why does ice float?

Why do water pipes burst when the water within freezes?

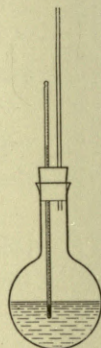


EXERCISE 45

WHAT HAPPENS WHEN WATER BOILS, AND AT WHAT TEMPERATURE DOES THIS TAKE PLACE?

Materials. A flask; a two-holed rubber stopper to fit; a thermometer; a glass tube; a ring stand with clamps (or other support).

Directions. Set up an apparatus as shown in the diagram. The flask should be about one half full of water into which has been dropped a few grains of sawdust or very small bits of porous paper. Note the temperature of the water, and then heat gently. Small bubbles will soon appear on the walls of the vessel, or rise through the water. Note the temperature when bubbles first appear. What are these bubbles? (Set a glass of cold water in the sun or near the radiator, and see if the same thing happens.) While heating, observe the movement of the particles and explain why they move as they do. When the temperature is near 100°C . or 212°F ., note the large bubbles which form at the bottom of the flask. What are these? Do they change in size as they rise through the water? What causes some to disappear completely? When the water is boiling vigorously, note its temperature. What occupies the space above the water in the flask? Allow it to boil for ten minutes, and then compare the volume left with the original volume. How do you explain the difference? What do you understand by the statement that water boils at about 100°C . or 212°F .?



Additional problems. What differences are there between ordinary water and steam?

Boil a half flask of water and, when at boiling temperature, remove the flame and stopper the bottle air-tight with a rubber stopper. Allow the flask and water to cool for five or ten minutes; then invert the flask and pour cold water on it. Explain what happens.

EXERCISE 46

HOW IS WATER DISTILLED, AND HOW MAY DISSOLVED SOLIDS BE SEPARATED FROM WATER ?

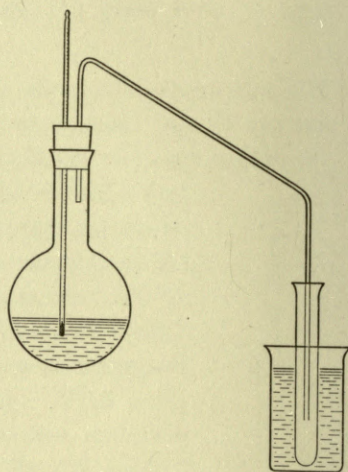
Materials. Apparatus of the preceding exercise; a bent glass tube; test tube; beaker or cup; salt.

Directions. Place about 100 cubic centimeters of water in a flask and add 3 or 4 teaspoonfuls of salt. Shake it to hasten solution. Taste the solution. Now connect a delivery tube as shown in the diagram, and heat the solution to boiling. Keep the water in the beaker cold by adding ice or snow. Observe what happens. After five minutes of boiling remove the beaker and test tube, also the burner. Taste the liquid that has distilled over into the receiver. This is called the distillate. Is any salt present?

Additional problems. Put ink or other colored liquid in a flask of water. Determine whether the coloring material is present in the distillate.

How could you obtain fresh water from salt water or sea water?

Of what commercial use is the process of distillation?



EXERCISE 47

WHAT EFFECT HAS EVAPORATION UPON TEMPERATURE?

Materials. A thermometer; cotton; alcohol; a small cup or drinking glass.

Directions. Record the temperature of the room. Twist a small piece of cotton about the bulb of a thermometer. This may be fastened on with a rubber band. Place the bulb in water which has stood until it is at about the room temperature. Record the exact temperature of the liquid.

Remove the bulb from the water. Watch the thermometer carefully, noticing and recording any temperature changes until no further changes occur. How do you account for the temperature changes which you have noted?

Wet the bulb of the thermometer again and fan it. How does its temperature change? Why? How does the temperature change when the bulb of the thermometer becomes dry? Repeat the experiment with the same thermometer and the same cotton covering, using alcohol instead of water. Explain the difference in results.

In your conclusions state what you have learned regarding the effect of evaporation and the rate of evaporation.

Additional problems. Put a drop or two of ether on the back of your hand and explain the sensation produced.

What are the principles underlying the use of ammonia in ice making?

Why do people fan themselves during hot weather?

When bathing in water which is cooler than the atmosphere, one may feel comfortably warm in the water but unpleasantly cool when out of the water. How may this fact be explained?

EXERCISE 48

HOW RAPIDLY DOES WATER EVAPORATE IN THE CLASSROOM?

Materials. A cup or beaker; a pair of balances with metric weights.

Directions. Fill a cup or beaker with water to within half an inch of the top. Weigh it and set it aside in an exposed place. Note the time when it was weighed.

On the next day or some succeeding day at the same time weigh again. How much evaporated during each 24-hour period? Secure the diameter of the cup in centimeters or millimeters, and calculate what depth of water evaporated from the cup. (One cubic centimeter, or 1000 cubic millimeters, weigh one gram.)

Additional problems. Assuming that evaporation would continue at the rate shown in the above experiment, what depth of water would evaporate in one year?

Perform the experiment of this exercise in the outdoor air, make calculations for the yearly evaporation as above, and compare the results with those secured from the schoolroom. Does this help to explain why one's nasal membranes become extremely dry during schooltime?

EXERCISE 48A

DOES ICE EVAPORATE?

Materials. Metal cup ; balances.

Directions. If Exercise 48 is performed during the winter, this exercise will be of much interest and can be done at the same time. Put water in a tin cup and set it outside to freeze. When the water is completely changed to ice, weigh it quickly and again set outside, so that it will remain frozen. On the next day and several following days weigh it again and record the results. What conclusion do you draw?

Additional problems. Why will wet clothes dry even if they are exposed to freezing weather?

What is the explanation of the fact that snow disappears during a period of days when the temperature is constantly at or below freezing?

EXERCISE 49

HOW RAPIDLY DOES WATER EVAPORATE FROM A PLANT?

Materials. A potted plant; a sheet of thin rubber (dentist's rubber) large enough to inclose the pot in which the plant grows; balances.

Directions. The plant should be well watered and then wrapped in such manner that water cannot evaporate from the soil or pot. To do this, wrap the pot in a sheet of thin rubber and tie so as to hold the rubber closely around the stem. This can be done more securely if the plant selected has but a single stem.

Weigh the pot and the plant after wrapping. Set it in a light place and weigh again from time to time — hourly, if possible. Record your weights in the table below.

What does a loss of weight indicate? Can you account for any changes in rate of evaporation? What are the reasons for wrapping the pot with rubber?

DATE	TIME	WEIGHT	LOSS PER HOUR

Additional problems. Water sometimes evaporates more rapidly from a vegetated area than from a similar area of free water. Explain this fact.

Why must house plants be watered more abundantly on dry, hot days than on cloudy days?

Determine the area of the leaves used in the above exercise and calculate the daily evaporation per square centimeter (evaporation occurs usually from the lower surface only).

EXERCISE 49A

DOES WATER EVAPORATE FROM A PLANT?

Materials. A large, wide-mouthed bottle; some fresh leaves or a short, leafy branch; materials arranged as in Fig. 62 of the "Elements of General Science."

Directions. If it is not desired to measure evaporation from a plant as in the preceding exercises, a simpler experiment may be used. Inclose several leaves (or a short, leafy branch) in a bottle without removing them from the plant. Close the mouth of the bottle with a split cork stopper, through which the branch or petioles pass, or plug the opening with cotton. Support the bottle in any convenient way and set the whole apparatus in a light place.

In about half an hour examine the bottle and explain the results.

EXERCISE 50

HOW DOES A SIPHON WORK ?

Materials. Rubber tube about 18 inches long ; two jars or pans, one of which will hold 1 or 2 gallons of water.

Directions. Two students should work together. Submerge the rubber tube in a jar of water so that the tube will be filled completely. Close one end by pinching and withdraw that end from the water, placing it in an empty jar with the end of the tube on the bottom of the empty jar. Release the tube, observe, and explain what happens. Allow the tube to remain until the water stops running. Compare the depth of the water in the two jars. What caused the water to run? What caused the water to stop running? Write complete notes on what you did and observed, and an explanation of the working of a siphon.

Additional problems. Why will a siphon fail to work if any part of the siphon tube is over 33 feet higher than the level of the water which is being siphoned ?

How can you remove the stale water from a goldfish jar and introduce fresh water without in any way disturbing the jar ?

A jar of clear liquid has a scum on its top. How can you remove almost all of the liquid with the least disturbance to the scum ? How can you start the siphon without submerging the entire tube in the liquid ?

EXERCISE 51

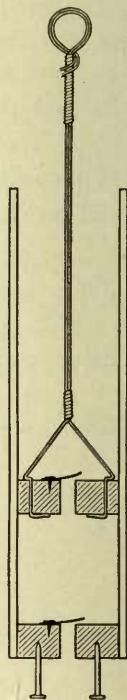
HOW DOES A LIFT PUMP WORK ?

Materials. A glass model of a lift pump or the following materials: some wire No. 16 in size; glass tubing from 1 to 2 inches in diameter and from 12 to 18 inches in length; two corks large enough to fit the tubing tightly; a piece of thin shoe leather or harness leather; tacks and shingle nails; a glass jar or pan.

Directions. This exercise is best demonstrated by a model lift pump.

If such a demonstration apparatus cannot be had, a crude one such as is shown in the diagram may be constructed by the teacher or students. Secure a glass tube from 1 to 2 inches in diameter and from 12 to 18 inches long. Cut two flat corks to fit the tube rather snugly. Bore a small hole through the center of each cork; then place a small, square piece of rather heavy sheet rubber or soft leather over the hole, and tack the piece along one of its edges. These pieces of rubber or leather will act as valves. Place one cork in the bottom of the tube, as in the diagram. A few small nails driven into the cork will keep the pump from the bottom of the jar when the pump is operated.

Cut three lengths of No. 16 ordinary iron wire 10 inches longer than the glass tube. Thrust these wires through the cork and clinch them below the cork, as shown in the diagram. Bend them above the cork as shown, and then twist the wires together to form a piston rod, making a circular handle above. Soak the valves well; place the piston in position and force it down, observing the position of the valves. Now raise it and observe what occurs. Again push downward and observe. Repeat, and see if the valves work in the same way as above. Why does the water rise in the tube during an upstroke? Write an explanation of the working of a lift pump, and make drawings to show the principal features.



Additional problems. How can a lift pump be made to lift water from a well more than 33 feet below the surface?

Why must a pump be "primed"? Why does water flow from the spout only on the upstroke of the lift pump?

How does a force pump differ from a lift pump?

EXERCISE 51A

HOW DOES A PUMP OPERATE?

Materials. An ordinary pump (cistern or pitcher pump).

Directions. Operate the pump slowly, observing all the facts about the flow of the water. If possible, take the pump to pieces sufficiently to find the plunger, its valve, and the valve at the bottom of the cylinder. Move the plunger up and down in a bucket of water and watch the action of the valve.

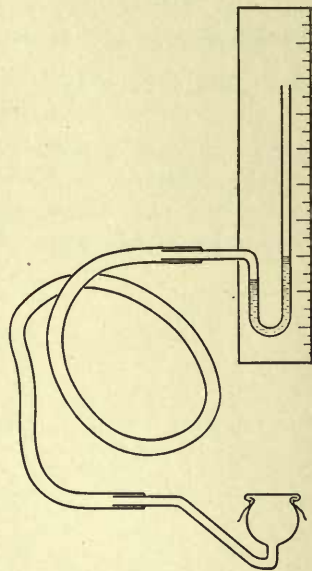
When thoroughly familiar with the pump, make a diagram showing all the important parts and write a description of the pump and of the way it works.

EXERCISE 52

IS THE LATERAL PRESSURE IN WATER DIFFERENT FROM THE PRESSURE DOWNWARD OR UPWARD?

Materials. Thin sheet rubber (dentist's rubber); a thistle tube; rubber and glass tubing; a funnel; a meter (or yard) stick.

Directions. Fasten a thin sheet of rubber over the end of a thistle tube or funnel. Prepare an indicator, which consists of a small glass tube bent as shown and tied or wired to a meter (or yard) stick, the tubing containing some ink or colored water. With a long rubber hose connect the thistle tube with the indicator. Lower the thistle tube to a certain marked depth with the rubber facing upward. Watch the change in level of the liquid in the long arm of the indicator tube. What does this change mean? With the rubber face of the thistle tube at the marked depth take the readings on the indicator. Change the position of the thistle tube so that the rubber faces sidewise, with its center at the same depth as before. Take readings again, and record. Place the thistle tube with the rubber facing downward, its center at the same depth, and again record the readings. What changes, if any, are noted in the level of the liquid in these three different positions? Upon what does the pressure in water depend? Would the readings be different if you placed the funnel in a larger jar at the same depth? Try it.



Additional problems. Why is a dam built wider at the bottom than at the top? Does the size of a reservoir govern the pressure?

EXERCISE 53

HOW CAN WATER BE USED IN FINDING THE VOLUME OF AN IRREGULAR SOLID?

Materials. A graduated cylinder; an irregularly shaped stone; a small cord or wire.

Directions. Fill a graduated (metric) cylinder about half full of water and read accurately the volume of water. Suspend a small stone by means of a thread or fine wire and lower it into the water. Again take the reading, and record. What is the volume of the stone in cubic centimeters?

Additional problems. Test the accuracy of the above experiment by use of objects of regular form which may be measured both as directed above and by linear metric measurements.

Determine the approximate volume of a large, irregular body as follows: Place a glass dish in a larger dish or jar. Completely fill the inner dish with water, but do not allow it to overflow. Slowly lower the body to be measured into the water, making certain that all overflow water is caught in the outer jar. Measure the overflow water in a graduated cylinder. What is the approximate volume of the object? What are the sources of error in this method of measurement?

EXERCISE 54

WHAT IS THE LIFTING EFFECT OF WATER UPON AN OBJECT IMMERSED IN IT?

Materials. The stone used in the preceding exercise; balance; cup large enough to contain the stone; small cord.

Directions. Dry the stone and weigh it. Suspend it from a balance by a thread in such a manner that the stone is immersed in water but does not touch the side or bottom of the vessel. Weigh while in water. Fill out the following table:

Weight of stone in air	
Weight of stone in water	
Loss of weight in water	
Weight of water displaced	
Volume of water displaced (1 cc. = 1 g.)	
Volume of stone	
Weight of one cubic centimeter of stone	
Stone is how many times heavier than equal volume of water	

Study this table and make a short, clear statement of the important facts you discover.

Additional problems. Is the method of determining volume as given in this experiment more or less accurate than that of the preceding experiment?

If the density of an object is the weight of a unit volume of the object, what is the density of the stone used in the above experiment?

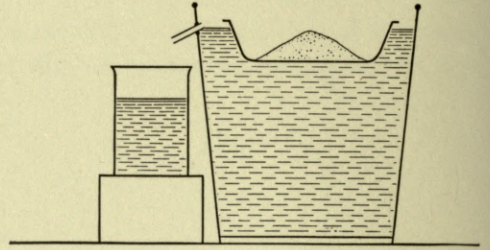
It has often been noticed that, when bathing, one can lift a large stone from the bottom to the top of the water, but cannot lift it above the surface. Why is this?

EXERCISE 55

WHY DO OBJECTS FLOAT IN WATER?

Materials. A shallow tin or granite pan; a galvanized iron pail; small piece of glass tubing; paraffin or sealing wax; beaker; dry sand; balance.

Directions. Punch a small hole in the side of the pail 2 or 3 inches from the top. Fit into the hole a piece of glass tubing 2 or 3 inches long, and seal water-tight where the tube passes through the hole in the pail. Fill the pail with water until water flows through the tube. Weigh and record the weight of the pan and beaker. When the water stops flowing, place the beaker under the tube ready to catch water which may flow later. Carefully lower the pan, allowing it to rest upon the water in the pail. Weigh and record the weight of the water which now flows into the beaker. Add a weighed quantity of sand and weigh the water which overflows. What is the relation between the weight of a floating object and the weight of the water it displaces?



Additional problem. Why will not a cast-iron kettle float? Why does an iron ship float? What is meant by the "displacement" of a ship?

EXERCISE 56

WHAT EFFECT DOES LAKE MICHIGAN HAVE UPON THE TEMPERATURE OF PLACES NEAR IT?

Materials. Cross-section paper; the data given on pages 138 and 142, "Elements of General Science."

Directions. Note the relative location of Madison (Wisconsin), Milwaukee (Wisconsin), and Grand Haven (Michigan) as shown on the map, p. 142 in the text, in order to understand why they are appropriate places for this study.

Compare first the figures given in the table for the coldest month (January) and for the warmest month (July). Which city is warmest in winter? Which is coldest? Which is hottest and which coolest in summer? Which place, therefore, has the greatest extremes and which is most equable? Study the data for the other ten months also, and find for yourself the answer to each of the following questions:

- a. How are the average winter temperatures of the three places related (that is, which is highest, intermediate, and lowest)?
- b. How are the temperatures related in summer?
- c. What is the difference between summer and winter temperatures at Grand Haven? at Madison?
- d. Could Lake Michigan be responsible for this difference?
- e. Write a statement of what appear to be the effects of the lake on temperature.

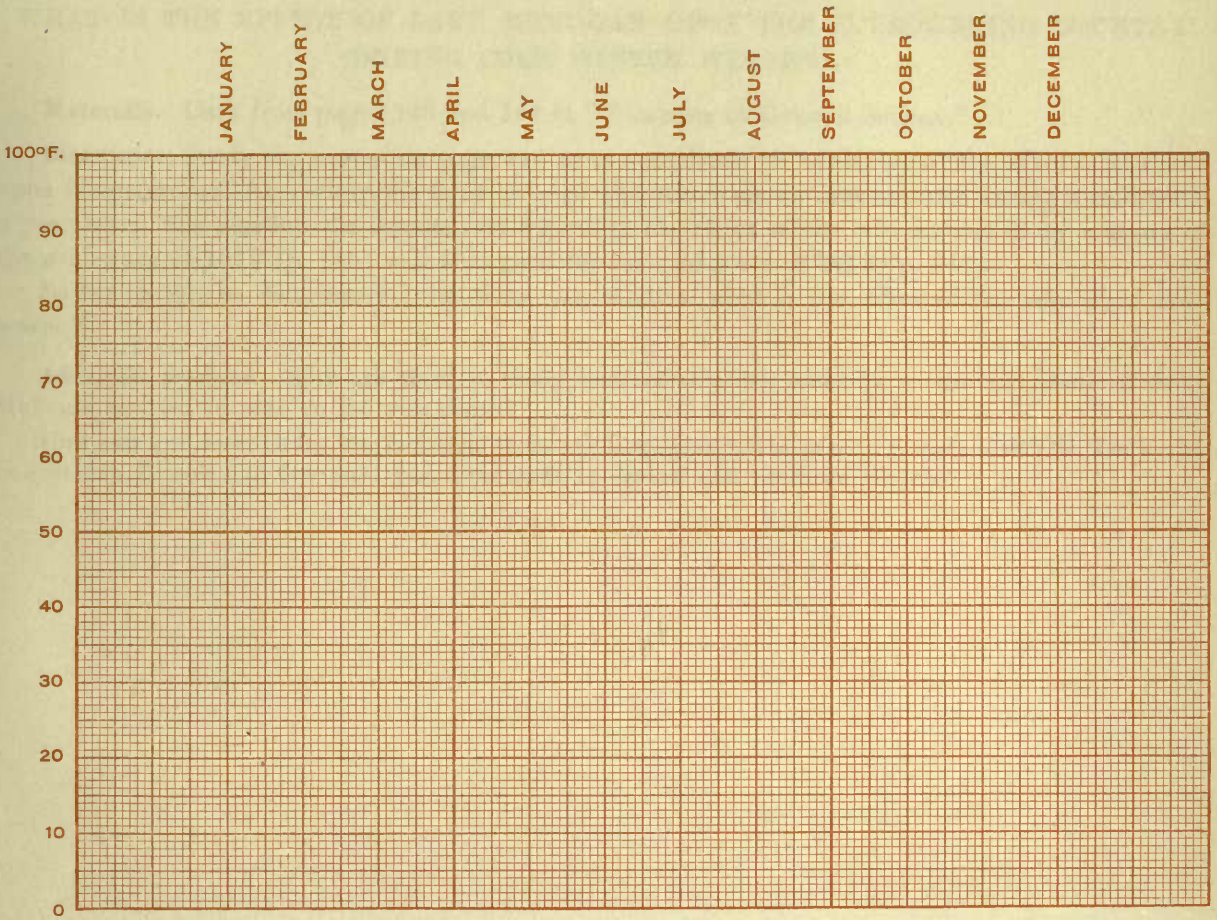
Your notes should include a clear statement of the subject matter of each question.

If the school is located near a large body of water, local data should be used in this exercise instead of those cited above.

The temperature relations discussed above will be seen more clearly if they are represented graphically. To do this, use a piece of paper which has been prepared as follows: On a piece of cross-section paper number the horizontal lines to correspond with the graduation of a Fahrenheit thermometer scale, placing the figures in the left-hand margin. Label twelve of the heavy vertical lines with the names of the months. Secure from the table the mean temperature for January at Madison (16.9°). Place a dot on the January line at a height to correspond with 16.9° on the thermometer scale at the left. In like manner represent the temperature at Madison for each of the twelve months. Connect these dots with a continuous line. Do the same for Milwaukee and for Grand Haven, using a different color for each.

Additional problem. Compare the temperatures at a given point in California, and at points in approximately the same latitude in the Rocky Mountain region, Central States region, and Atlantic Coast region.

EXERCISE 56



EXERCISE 57

WHAT IS THE EFFECT OF LAKE MICHIGAN UPON THE SURROUNDING COUNTRY DURING COLD WINTER WEATHER?

Materials. Data from pages 143 and 144 in "Elements of General Science."

Directions. Study the curves on page 143 of the textbook for evidences of the effect of the lake upon temperatures. Also study the table on page 144, which shows temperatures during a cold wave a year later. See whether the conclusions regarding the effect of the lake arrived at by a study of the cold wave of 1912 (p. 143) will hold good for the cold wave of 1913 (p. 144).

So far as can be determined from these two studies, what is the effect of the lake upon cold waves?

Additional problems. Why are there so many productive peach orchards on the east shore of Lake Michigan and few or none on the west shore?

How can you account for the fact that there are large productive peach orchards about St. Louis and in southern Illinois and few good peach orchards in central and northern Illinois?

EXERCISE 58

IS THERE A DIFFERENCE IN THE RATES AT WHICH SOIL AND WATER CHANGE IN TEMPERATURE?

Materials. Bunsen burners or alcohol lamps; metal cups or pans (not soldered); soil; water; thermometers.

Directions. Arrange two Bunsen flames, or alcohol-lamp flames, to burn as nearly alike as possible. Place about 100–200 grams of dry soil in a cup and an equal weight of water in a second cup. Take the temperatures of both and leave a thermometer in each; then place them over the burners at the same time. When one reaches about 100°C . or 212°F ., note the temperature of the other and record both. Which heats more rapidly?

Additional problems. If a 5-pound piece of iron at 100°C . be dropped into a vessel containing 5 pounds of water at 0°C ., the water will be warmed and the iron cooled. What is the temperature at which the water is no longer heated by the iron?

On the beach at noon of a bright summer day, is the sand of the beach or the water warmer? Do the same temperature relations exist at midnight? In the beginning of winter weather does the sand along the shore or the water freeze first?

Which heats more rapidly upon a stove, a kettle of water or an iron of equal weight?

EXERCISE 59

WHAT ARE THE PRINCIPAL CHARACTERISTICS OF HARBORS AND WATERWAYS?

Materials. Maps or charts of waterways or ports.

Directions. Base this study upon maps or charts of the nearest port or waterway through which the commerce of the local community passes. Excellent charts of navigable waters may be obtained at nominal cost from the proper government authorities. Lists and prices of such charts may be secured free as follows:

Coasts of United States

United States Coast and Geodetic Survey, Washington, D.C.

Great Lakes

United States Lake Survey Office, Detroit, Michigan.

Mississippi River

Mississippi River Commission, St. Louis, Missouri.

On such charts note depths, obstructions, channels, lights and lighthouses, buoys, fog signals, wharves, and other facilities for safety and for loading and unloading. The conditions vary so greatly that it must be left to the teacher to direct the detailed work. If the school is very remote from water transportation, the exercise may be omitted.

Additional problem. With a leading product as a basis for discussion, as cotton, wheat, coal, iron, or lumber, indicate the points to which the major part of the output is shipped and the chief routes of shipment, and thus show the extent to which water enters into the transportation of this product.

EXERCISE 60

WHAT IS THE LOCAL IMPORTANCE OF WATER TRANSPORTATION ?

Materials. Reports of the United States Department of Commerce and Labor dealing with quantities of materials shipped by water, and the sources and destinations of these materials; reports or data from individual steamship companies regarding number of boats in use through a given river or from a given port, the amount of material shipped, its nature, source, and destination; statements from local merchants regarding the nature, source, and amount of goods they receive by water transportation.

Directions. If the local community is affected by water transportation, discover what proportion of goods shipped to or from the place travels by water, what kinds of goods are more frequently sent by water, what the cost is per ton by rail and by water, and how the time needed for delivery by water compares with the time by rail.

What is the importance of water transportation to your community ?

Additional problems. What influence did waterways have upon the establishment of New York City ? of Philadelphia ? of San Francisco ? of New Orleans ? of St. Louis ? of Pittsburgh ? of Seattle ?

What cities or towns of your immediate community are there whose location was affected by waterways ?

EXERCISE 61

WHAT IS THE RELATION BETWEEN WATER SUPPLY AND DISEASE?

Materials. Data given in Figs. 79, 81, and 82 in the "Elements of General Science"; any additional similar data which are available.

Directions. The above question may be answered by study of the death rate from typhoid fever in relation to the character of water supply.

Examine Figs. 79, 81, and 82 in the textbook. Explain in full to what extent typhoid appears to be a controllable disease and how far proper water supply may assist in controlling it. Give the facts on which you base your opinion.

Additional problems. How do the leading American and European cities compare relative to proportionate deaths from typhoid? How may any difference be explained?

Are rivers likely to be the best sources of water supply?

EXERCISE 61A

WHAT IS THE SIGNIFICANCE OF THE LOCAL DEATH RATE FROM TYPHOID?

Materials. Local records regarding number of cases of sickness and death from typhoid. These records should be available in the office of the local health officers, and those covering a period of years will be needed.

Directions. Secure the local death rate from typhoid if possible. Consult the board of health or health officer. If there are no such officials, consult the physicians or the state board of health. The same authority should be able to give you the typhoid rate in a number of other places. How does your community compare with others? If its rate is not so low as some others, try to learn why.

Additional problem. What is the relation of flies to distribution of typhoid? Would there be danger of securing typhoid germs from flies if all typhoid material from persons ill with typhoid were sterilized? What are the reasons for the campaign to prevent the reproduction of flies?

EXERCISE 61 B

WHAT IS THE CHARACTER OF THE LOCAL WATER SUPPLY?

Materials. Data regarding the local water supply, the pump, pumping plant, source of water, methods of carrying water, and care in its use.

Directions. If there is a municipal water system, visit the pumping station. Learn from what kind of source the water comes; what precautions are taken to protect it from contamination or to purify it; whether the supply is sufficient and the cost such that all citizens can use it freely. Find out also whether tests of the quality of the water have been made, and how much is really known, and how much assumed, regarding its healthfulness.

Are the citizens in the habit of attempting home purification by filtering, boiling, or other means?

If some families secure water from wells, visit some of these localities and note what precautions are taken to protect the wells from contamination by surface water, cesspools, stables, etc. Are these precautions likely to be effective?

What is your opinion of the probable healthfulness of drinking waters in your community? How could conditions be improved?

Additional problems. What are the chief methods of securing adequate water supply in other communities near you? in the leading cities of the United States?

Is it better and more economical for each family to be depended upon to purify its water or for the community to do this for all?

EXERCISE 62

HOW IS SEWAGE DISPOSED OF IN YOUR COMMUNITY?

Materials. Data and observations upon the local methods of sewage disposal.

Directions. Does your community have a municipal sewerage system? If so, describe its principal features. Are most of the houses connected with the system? Is it important that all should be connected? What is the final disposition made of the sewage? Is this disposition safe as far as your community is concerned? Does it menace the health of any other community?

If there is no sewerage system in your community, why not? Would the installation of one be an important public improvement?

Prepare a summary, stating the principal needs of your community with reference to this matter.

EXERCISE 63

HOW ARE PULLEYS USED AS MACHINES, AND WHAT ARE THE ADVANTAGES OF DIFFERENT SYSTEMS OF PULLEY ARRANGEMENT ?

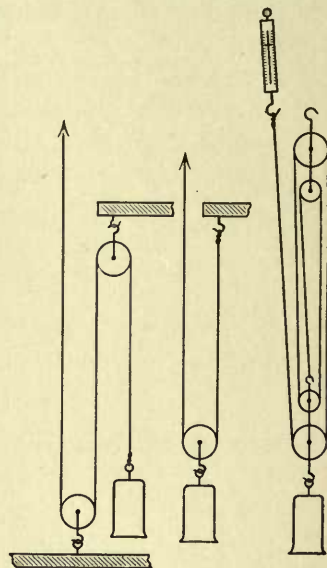
Materials. Some single and double pulleys ; a sensitive spring balance ; weights ; some small cord.

Directions. Arrange a pulley, spring balance, and weight as shown in the figure at the right of the diagram. The weight should be 100 grams or 200 grams. Attach the spring balance and raise it through a known distance, noting and recording at the same time the distance through which the weight rises. Now raise and lower the balance several times, taking as many readings while raising as while lowering. Average the readings. This is the reading that should be secured if there were no friction. Why ? Keep a record of all your measurements and readings. Tabulate the averages in the blanks given below.

Arrange an apparatus as shown in the central figure and again make record of your results.

Do the same with the arrangement as shown at the left.

Having secured your data as above, compare the force applied at the end of the cord, the weight lifted, and the number of strands of cord supporting the weight ; and from this state (1) the mechanical advantage of the pulley system you are using ; and (2) the rule whereby one may always tell from inspection of any pulley system what advantage it will give. This last statement should not be made until the results secured by all members of the class have been tabulated on the board and compared.



ARRANGEMENT OF PULLEYS	NUMBER 1	NUMBER 2	NUMBER 3
Average force used in raising			
Average force used in lowering			
Average up-and-down readings			
How much greater is weight than force			
Strands of cord supporting weight			

Additional problems. What is the advantage of using pulleys in lifting hay when stacking it or putting it into barns ?

If a piano weighing 1000 pounds is to be moved from the street level to the fourth floor of a building 60 feet from the street level, and two men are to pull a total of 250 pounds in lifting the piano, what arrangement of pulleys and ropes will enable them to lift the piano (friction being neglected) ?

EXERCISE 64

HOW TO MEASURE THE WORK DONE BY THE FORCE APPLIED IN A PULLEY SYSTEM IN RAISING A KNOWN WEIGHT A GIVEN DISTANCE

Materials. Data from Exercise 63.

Directions. Tabulate your results from Exercise 63, in the first arrangement of pulleys, as follows :

Weight lifted . . . . .	..... gm.
Distance through which lifted . . . . .	.....cm.
Force applied upward . . . . .	.....gm.
Distance through which force is applied . . . . .	.....cm.

Calculate in centimeter grams the work done by the force applied to lift the weight a given distance for the first pulley arrangement in Exercise 63. These calculations should be made according to directions given in the textbook.

Additional problems. Calculate the work done in lifting the weight through the same distance as above by the second arrangement in Exercise 63.

Make calculations for the third arrangement in Exercise 63.

Compare the amount of work done in the three cases.

Compare also the force applied and the distance through which the force is applied.

What advantage, if any, is secured by using the first arrangement? Do the other arrangements offer any advantages?

EXERCISE 65

HOW MUCH WORK IS DONE UPON THE WEIGHT (WORK OUT) IN EXERCISE 63 ?

Materials. Data from Exercise 63.

Directions. Secure from the first pulley arrangement in Exercise 63 the following data :

The weight lifted . . . . .	.....gm.
Distance the weight is lifted . . . . .	.....cm.

Calculate the work done upon the weight.

Additional problems. In a manner similar to the above determine the amount of work accomplished upon the weight if it is lifted the same distance by use of each of the three arrangements of pulleys. Does the work accomplished differ in each of the three cases ?

Can you determine the amount of work done in the second additional problem in Exercise 63 ?

EXERCISE 66

WHAT IS THE EFFICIENCY OF A PULLEY SYSTEM?

Materials. Data from the two preceding exercises.

Directions. Secure from the two preceding exercises the following data:

Useful work out	
Total work in	

What percentage of the work in is secured in work out? Under what conditions could work out equal work in? What would be the percentage of efficiency when work out equals work in?

Additional problems. How do you account for the fact that the amount of work done upon a pulley system is greater than the amount of work secured from it? What becomes of the work wasted?

Is it possible to construct a machine from which as much work or more work may be secured than the amount of work put into it? Do you know of any such machines?

EXERCISE 67

CAN ONE KIND OF ENERGY BE CHANGED INTO ANOTHER KIND ?

Materials. Some wire nails or small pieces of iron wire ; a piece of iron or a stone to serve as an anvil ; a hammer ; some copper wire ; a rubber or ebony rod ; a piece of flannel cloth.

Directions. By holding a nail or wire in the hands, note its temperature. Place the nail or wire on an anvil or heavy piece of iron and strike it several blows with a hammer. Now pick up the nail or wire and note its temperature. How do you account for the change in temperature ?

Bend a copper or iron wire several times and then feel the part where the bending took place. Explain your result.

Write your answer to the above question, giving the results of the experiments and stating your conclusion.

Additional problems. Rub a rod of rubber or ebony, or a fountain pen, with a piece of flannel, and then bring it to your ear. What kind of energy was present on the rod ? How did it come to be there ? Rub the rod again and bring it near some very small scraps of paper. What is the result ?

Why does an ungreased wagon or carriage axle become hot when used ?

When sawing wood, does the saw become heated ? Does the wood become heated ? Why ?

How did uncivilized tribes of men start their fires ? What principle is involved in this method of starting fires ? Can you start a fire in the same way ?

EXERCISE 68

WHAT IS THE PRINCIPLE OF THE STEAM ENGINE?

Materials. A model of a steam engine, a toy engine, or a visit to a steam engine. If a model is not available, the diagram on page 184 of the "Elements of General Science" should be used; also, diagrams furnished by manufacturing firms will be helpful.

Directions. Examine a model of a steam engine if one is at hand, and learn how it works. Make a drawing of the principal parts of the engine, and label all parts to show how steam enters and leaves the cylinder and how the piston is affected. Indicate by arrows the direction of the steam. How is the energy transmitted to the wheels of the engine? In labeling your drawing and in writing any additional notes, consult the drawing in the textbook for proper names of parts.

If no model is at hand, examine the cylinder of an engine and its valves and piston, to learn how it works. If neither the model nor the engine is available, make a drawing similar to that in the text and explain in your own words how such an engine works.

Additional problems. When the steam leaves the engine, do you think all of its energy has been used?

What is the importance of the use of steam engines in industries? How many kinds of steam engines do you know?

EXERCISE 69

WHAT IS THE NATURE OF THE PARTICLES WHICH MAKE UP THE SOIL?

Materials. Glass tubing $\frac{1}{2}$ inch in diameter and 2 feet or more in length; cork stoppers; soil.

Directions. Close one end of a glass tube with a cork stopper. Different students may perform the following experiment by use of different kinds of soils. Mix some soil with water to the consistency of a thin mud, and pour in enough of the mixture to fill the lower end of the tube 3 or 4 inches. Add water to fill the tube. Close the upper end with a cork stopper, invert the tube, and stand it in a vertical position. Watch the particles as they settle through the water.

What differences are there in the materials which settle first and those which settle later? Why do some particles settle before others? Describe the sediment with reference to the various-sized particles and the parts of the sediment in which the particles are too small to be seen with the unaided eye. Do you suppose that there may be some of the particles which have not yet settled? If so, where are they and why have they not settled? If allowed to stand for several days, will all particles settle?

Do the samples of soil used contain both rock materials and organic materials?

Additional problems. If a very long tube (5 or 6 feet) is used, a more complete separation of materials will be made. Such a demonstration will prove instructive.

If a microscope is available, small pieces of soil should be studied under magnification. Such studies will enable students to determine the form and structure of soil particles.

EXERCISE 69A

WHAT IS THE CHARACTER OF THAT PART OF THE SOIL IN WHICH NO PARTICLES CAN BE SEEN WITH THE UNAIDED EYE?

Materials. A microscope; some of the muddy water and finest of the soil particles from the preceding experiment.

Directions. Place a drop of the muddy water from the preceding experiment on a glass slide, and examine with the low power of the microscope. (Do not use the high power of the microscope unless so directed by the teacher.) Examine also a very little of the top part of the sediment mixed with water on the slide. There should be only enough sediment to make the water on the slide appear cloudy. Examine a third sample from that part of the sediment in which very small particles are visible to the naked eye.

Describe the material in each case, and state what is shown regarding the structure of soil.

Additional problems. Are there small soil particles which seem to differ from the large ones only in size?

Are there small particles which differ from large ones in their nature as well as in size?

Does a fertile soil usually contain more or fewer of the fine soil particles than do poor soils?

EXERCISE 70

HOW MUCH WATER MAY BE HELD BY SOIL?

Materials. Glass dishes; balances; drying oven, radiator, or stove; soil.

Directions. For this exercise soil should be used which is directly from out of doors. Weigh a small dish, fill it with the soil, and weigh again. Set the dish in a dry, warm place and weigh at intervals as long as the soil continues to lose water as indicated by a decrease in weight. At the last it should be placed in a drying oven at a temperature slightly above the boiling point. If an oven is not available, a radiator or stove may be used, but the results will not be so accurate. Tabulate your results as follows:

Weight of dish	
Weight of soil and dish	
Weight of soil	
Loss of weight (equals evaporated water)	
Weight of dry soil	
Water is equal to what per cent of the dry soil	

Save the soil and keep it dry for a later experiment. Note that the percentages in this and the following exercises are all calculated with reference to dry soil.

Additional problems. Take samples of soil from the first 2 inches of the surface, from a depth of from 6 to 8 inches, and from a depth of from 14 to 16 inches. Determine the relative percentages of water in soil at the different depths.

Saturate a soil with water; then determine what percentage of water it contains.

When a plant wilts because it cannot longer secure water from the soil, is the soil perfectly dry?

EXERCISE 70A

WHAT IS THE WATER-RETAINING CAPACITY OF DIFFERENT KINDS OF SOIL?

Materials. Glass tubes used in Exercise 69; cork stoppers.

Directions. Fasten a glass tube in a vertical position. Close the bottom with a stopper which has had a notch cut on one side to allow water to leak out. Put a piece of blotting paper in the bottom of the tube on the stopper, if necessary, to hinder the soil from falling through the hole.

Fill the tube two thirds full of dry soil, the weight of which has been ascertained. Press the soil down lightly. Pour in measured quantities of water (distilled water if possible) from time to time, until the soil is soaked to the bottom. Catch the water, if any, that filters through. When the water has ceased to come through, measure it and compare with the amount poured into the tube. Calculate the amount of water retained per gram of soil.

Several different types of soil should be used by different members of the class and final results compared. If soils containing much clay are used, the water will pass through very slowly.

Additional problems. Do different kinds of soil have different capacity for water?

What relation is there between capacity for water and drainage of soils?

EXERCISE 71

IS THERE ANY SOLUBLE MATERIAL IN THE SOIL?

Materials. Fertile soil; a large funnel; filter paper; distilled water; a glass dish.

Directions. Fold and place filter paper against the inner surface of the funnel; then fill the funnel with soil. Place the funnel with its tube above a clean glass dish, pour distilled water upon the soil, allowing the water plenty of time to pass through the soil and the filter paper into the dish below. Set the dish in a warm place and evaporate to dryness. Explain the presence of anything which remains in the dish after the water has evaporated.

Additional problem. Is there danger of soils losing fertility through drainage?

EXERCISE 72

WHAT IS THE AMOUNT OF ORGANIC MATTER IN SOILS?

Materials. Samples of dry soil, such as resulted from Exercise 70; a metal pan; Bunsen burner or a large alcohol lamp.

Directions. The pan should be weighed before the soil is put in, and also with the soil, the weights being recorded. Heat the soil to a red heat over any convenient flame, and continue until all the dark material appears to be burned. Weigh again when cool. Tabulate as follows:

Weight of pan	
Weight of pan and soil	
Weight of soil	
Loss by burning (equals organic matter)	
Percentage of organic matter	

Additional problem. Secure samples of soil from a swamp or peat bog, also from a sandy region and a river flood plain; determine the percentage of organic matter as above; compare and explain differences in these percentages. Does there appear to be any relation between soil fertility and amount of organic matter in soils?

EXERCISE 73

HOW ARE SOILS FORMED ?

Materials. The local environment; soil-survey reports bearing upon local soils; discussions found in library materials.

Directions. An excursion should be made into the adjacent country to study the soils. River-bottom lands and uplands should furnish contrasting types of soils. Differences in both crops and natural vegetation in correspondence with soil differences may be seen. Visit a rocky ridge or ravine and study formation of soil by weathering, plant action, and stream work. If the region is within the glaciated area, look for evidences of glaciation and glacial soils.

Find out whether the area about the school has been surveyed by the Bureau of Soils, Department of Agriculture, Washington, D.C., and if so, secure a copy of the report. This will give map and details regarding soil types. The details of all such studies will change with the locality and must be left to the pupils and teacher.

Additional problem. How many types of soils are there in your locality? Can you determine the causes of the differences in these soils? How do these soils differ with reference to production of crops?

EXERCISE 74

HOW DOES EROSION AFFECT SOILS ?

Materials. Banks and riffles of a lake, river, or ditch.

Directions. This study is best carried out by a field visit to a running stream, a lake shore, or a hillside where ravines have been formed. An open drainage ditch will usually furnish a good basis for this work.

Observe the running water to determine whether it is carrying any soil particles. Does rapidly running water carry more material or larger material than slowly running water? Where does the material come from? What becomes of this material? How does the carrying power of water change with changes in its rate of flow? What evidences upon this question are there along banks and riffles of lakes, streams, and ditches?

Additional problems. Arrange an erosion model in a sink in the following manner: Fill one end of the sink with sandy or gravelly soil; close the outlet of the sink by use of a stopper through which a short glass tube is inserted so that an inch or two of water will stand in that end of the sink before the water overflows; by use of a tube allow a small stream of water to run very slowly upon the soil farthest from the outlet. Observe the development of channels, and the deposit of materials.

If in an open field erosion is allowed to continue unhindered, what results will follow?

Is it the better or poorer parts of the soil which are usually lost by erosion?

EXERCISE 75

CAN THE ROOTS AND STUMP OF A PLANT FORCE WATER UPWARD?

Materials. A plant with a stem about $\frac{1}{4}$ inch in diameter (a potted plant or one growing out of doors will serve for the exercise); glass tube with small opening; rubber tubing of size to fit closely over the stem and glass tubing; small cord or copper wire.

Directions. Arrange apparatus as follows: Cut off the top of the plant about 2 inches above the ground. To the stump of the stem which is connected with the roots attach a glass tube by means of a short piece of rubber tubing, and support the glass tube in a vertical position. It may be best to insure a tight joint by wrapping the tube tightly with cord or wire. A glass tube with a small bore will give more striking results. Water the soil freely and observe the apparatus at intervals of a few hours to see if water is being forced out of the cut end of the stem. If water is forced upward, determine the amount and the rate of rise.

Additional problem. If a grapevine is cut in the springtime it "bleeds." Why? When maple trees are tapped, what is the source of the water which comes from the wound?

EXERCISE 76

HOW DOES A PLANT ABSORB WATER ?

Materials. A short-stemmed thistle tube or a metal cup (known as the Lyon Osmometer), such as is shown on page 235 of "Elements of General Science"; glass tubing; rubber tubing; small cord or copper wire; some thick sirup, sugar solution, or salt solution; parchment paper, or animal bladder, or sausage casings.

Directions. Close the stem of the thistle tube or metal cup and place the cup with the stem downward; pour the sirup or other thick solution into the cup and fasten the membrane securely over the opening of the cup; turn the cup with the stem upward and open the stem; by means of rubber-tubing connections fasten a long glass tube to the stem of the cup; stand the cup in a dish of pure water and fasten the tube securely; observe the apparatus at intervals for three or four days and record observations. How are the results of this experiment similar to those of Exercise 75? How different? In what ways does this experiment explain how plants secure their water?

Additional problems. Bore a hole in the top of a beet or carrot; place sugar in the hole until it is almost full; stopper the hole with a one-holed rubber stopper, a glass tube having first been inserted; set the apparatus in a vessel of water; and support the glass tube in an upright position. Observe as in the above experiment.

When a strong salt solution, such as that from an ice-cream freezer, is poured upon the lawn, the plants upon which it is poured usually die. Why?

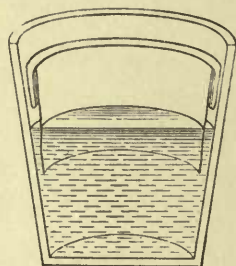
What is the explanation of the common practice of putting a handful of salt upon the cut stems or roots of weeds?

EXERCISE 77

WHAT ARE ROOT HAIRS?

Materials. Drinking-glasses; filter paper; seeds of radish, mustard, or oats.

Directions. Cut a strip of filter paper 4 inches wide and 2 inches longer than the circumference of the glass at its top. Fold the paper lengthwise with each fold 2 inches wide. Turn and crease one fold again, thus making a short fold each side of which is 1 inch in width. With a needle or pin perforate the crease of the short fold in many places, and place seeds in this fold. Place the filter paper with the wide fold innermost around the upper inner wall of the drinking-glass, allowing the ends to fit together. Pour water into the glass until the lower part of the wide fold is wet. The water will then cause the filter paper to adhere to the glass and will moisten the seeds. Observe from day to day, and as they develop describe the roots and root hairs with reference to general appearance, length, diameter of hairs, location of hairs on roots, and abundance of hairs.



Additional problems. If a microscope is available, mount some of the root hairs, together with the root from which they grow, and make a detailed study, showing the exact relation which exists between the root hairs and the surface cells of the root. Determine where the young root hairs are developing. How do they grow? Can you estimate the proportionate surface exposure of root hairs as compared with that of the roots from which they grow?

Plant seeds such as those used above in dishes of moist sawdust or sand; when the young plants have developed until a good supply of root hairs are formed, carefully pull up some of the plants. To what parts of the root system is most soil attached? What holds the soil? What is meant by "anchorage in the soil"?

EXERCISE 78

WHAT IS THE PATH OF WATER IN PLANT STEMS?

Materials. Freshly cut leafy stems of both soft and woody plants; red ink or water which has been colored by addition of eosin or other coloring material.

Directions. Stand freshly cut leafy stems in a colored solution. Very leafy stems, if placed in a sunny location with good circulation of air, may be ready for examination in half an hour. In many cases it will be well to allow the material to stand until the next day.

Examine the stems by cutting across the stem at intervals or by peeling off the surface. If blanched celery, yellow coleus, or other light-colored plants are used, the stems will be sufficiently transparent to show the red color without cutting. Can the course of the solution be traced into the leaves? Are there definite tissues through which the solution passes? Diagram a cross section of the stem and a surface view of a leaf to show any point observed regarding definite tissues through which water passes.

Additional problem. How would the passage of water in a woody plant be affected if a ring of bark were removed from the stem? What would be the effect if the ring included the bark and all of the new wood?

EXERCISE 79

WHAT FOOD MATERIALS ARE PRESENT IN PLANTS ?

Materials. The following are convenient for this exercise: potato, turnip, carrot, radish, apple, orange, rice, beans, oat grain, wheat grain, corn grain, or the products of these, as oatmeal, flour, commercial starch, etc.; iodine solution; Fehling's solution; nitric acid; ammonia; some test tubes.

Directions. The tests for food substances which may be made most readily are the following:

a. Starch. Crush or scrape some of the material to be investigated, and boil it in water in a test tube. When cool, add iodine and note the resulting color. If commercial starch is used, first the reactions may be seen with material that is known to be starch, and later tests for the presence of starch in other materials will be made more accurately.

b. Grape sugar. Crush or scrape, add water, boil, add 1 or 2 cubic centimeters of Fehling's solution, and boil again. If grape sugar is present, the solution will soon be clouded by a red precipitate, which will settle to the bottom.

c. Protein. Crush or scrape the material and boil in water to which a few drops of nitric acid have been added. A yellow color indicates protein, and this is changed to an orange by the addition of ammonia. Since most of the plant proteins encountered are not soluble, the color will appear upon the fragments rather than in the solution.

In the above experiments record your results in the blanks given below, checking for each material the food substances which are found to be present:

MATERIAL TESTED	STARCH	SUGAR	PROTEIN

Additional problems for this exercise may be added indefinitely by testing such plant materials as are available.

EXERCISE 80

IS STARCH SOLUBLE IN WATER ?

Materials. Powdered starch ; iodine solution ; test tubes.

Directions. Put a small amount of starch in cold water in a test tube. Add sufficient iodine solution to color the starch, and shake the mixture thoroughly. Set it aside and observe from time to time, as the starch settles, to see whether any of the starch remains permanently and evenly distributed throughout the water, as will be the case if the starch is dissolved.

In another test tube place a small amount of starch in water and heat to a boiling temperature. When cool, add a few drops of iodine solution. Set it aside until the following day. If the starch is dissolved the liquid will remain colored throughout, but if the starch is not dissolved part or all of the liquid will be clear.

Additional problems. When using starch in laundry work the water in which the starch is placed is usually heated. Why ?

From the above experiments do you infer that starch can pass readily from one part of a plant to another part ?

EXERCISE 81

CAN STARCH BE DIGESTED (CHANGED INTO A SOLUBLE SUBSTANCE) OUTSIDE THE BODY OF A PLANT OR ANIMAL?

Materials. Test tubes; starch paste; malted barley or barley grains; iodine solution and Fehling's solution.

Directions. Partly fill a large test tube or a cup with starch paste made by boiling a half teaspoonful of starch in a half pint of water.

Prepare a malt extract by securing some dry malted barley and grinding it in a mortar or a coffee grinder; soak 1 or 2 tablespoonfuls of the barley in a cupful of water for an hour; filter off the water, which with the substances in solution is the malt extract.

If malted barley cannot be had, soak some fresh barley grains in water for from ten to twelve hours, pour off the water, and place the barley in a closely covered dish in a warm place to germinate. When the sprouts are an eighth of an inch long, crush the barley, soak in water, and treat as above.

To a test tube of starch paste add 1 or 2 cubic centimeters of the malt extract. Allow the mixture to stand for at least half an hour, preferably in a warm place. It may stand overnight with advantage. Test a small sample for starch. Test another sample for grape sugar.

What change has taken place as to the amount of starch? of grape sugar? How do you account for these changes?

NOTE. There is always some sugar in the malted barley, and this will be dissolved in the malt extract. Sugar is, therefore, added to the starch paste with the malt extract, but if a small amount of the extract is used, the amount of sugar added will not be great. Some of the pupils may wish to test the malt extract diluted with water instead of starch paste, to determine whether or not all the sugar in the above test was originally in the malt. They should devise their own method.

Additional problems. Put some powdered starch in cold water in a test tube, add a small amount of malt extract, and leave in a warm place for twenty-four hours or more. Test with Fehling's solution to see if sugar is present.

If a microscope is available, examine starch grains which were used in the preceding problem and compare them with starch grains which have not been treated with malt. Do any of the grains show evidence that they have been partly dissolved?

EXERCISE 82

HOW IS FOOD DISTRIBUTED THROUGH THE HUMAN BODY?—THE FLOW OF BLOOD IN THE VEINS

Directions. Allow the arm to hang downward; grip the arm tightly above the elbow and note the location and appearance of the veins of the lower arm. Then releasing the pressure on the upper arm, hold the arm pointing upward and note the change in the appearance of the veins. Account for this difference. Place your finger on a prominent vein and note the appearance of the vein on both sides of the finger. Can you in this way determine the direction of the flow? Do you feel any pulse beat in the veins?

EXERCISE 83

THE FLOW OF BLOOD IN THE ARTERIES

Directions. Most of the arteries lie deep in the tissues, but they may be recognized by their "beat." Examine the right-hand wrist with the tip of the finger and locate the artery on the palm side of the wrist near the base of the thumb. Locate the arteries of both wrists. Count the number of beats per minute. Repeat to verify. Find also the carotid artery in the side of the neck, the small artery at either side of the nose just below the eye, and the artery just in front of the ear. What is the average number of heartbeats per minute for your entire class? What are the greatest individual variations?

Additional problems. When an injury results in cutting a large blood vessel, how can you distinguish whether it is an artery or a vein?

If an artery were cut at the elbow, where should the bandage be placed in order to stop the bleeding?

EXERCISE 84

OF WHAT DOES THE BLOOD CONSIST?

Materials. A compound microscope; a cover glass; vaseline; a needle; alcohol.

Directions. This experiment should be done by the instructor as a demonstration. Sterilize a sharp needle by holding it in a flame for a few moments. Wash the ball of the middle finger of the left hand with alcohol. Tie a piece of cloth quite securely around the first joint, and then with a quick thrust of the needle puncture the skin. A drop of blood will quickly collect. This should be transferred to a glass slide. A cover glass which has had vaseline applied to its edges should be placed over the drop in order to seal it. Can you distinguish the liquid of the blood from the solid bodies (corpuscles)? What is the nature of the corpuscles? Where is most of the coloring matter of the blood?

Additional problem. If prepared slides with corpuscles properly stained are available, make a detailed study of both red and white corpuscles, and make drawings to illustrate their structure.

EXERCISE 85

HOW DOES THE BLOOD CIRCULATE THROUGH THE CAPILLARIES?

Materials. A compound microscope; a frog; a board such as a chalk-box cover, with a glass slide fastened over a V-shaped notch in one end of the board; chloroform or ether.

Directions. Anæsthetize a frog by placing it in a small jar and adding a few cubic centimeters of chloroform or ether. When the frog is completely under the influence of the chloroform or ether, so that it will not withdraw its foot when extended, place one of its feet under the microscope so that a part of the web is in focus, and hold it in position. Observe the flow of the blood, the color of the blood, and any other points which you can see. What seems to be the rate of flow of the blood in capillaries as compared with arteries and veins? As the frog comes from under the influence of the anæsthetic, is there any change in the rate of flow of the blood?

Additional problem. Mount a small fish or a tadpole so that the microscope shows the thin flesh of the tail, and observe the circulation through the capillaries. This experiment may be used instead of the above, no anæsthetic being necessary.

EXERCISE 86

WHAT ARE THE VALUES OF DIFFERENT KINDS OF FOODS?

Materials. The data presented on page 243 of the "Elements of General Science."

Directions. It is commonly supposed that an average man needs for his daily food supply approximately the following amounts of the different kinds of food:

Protein	$4\frac{1}{2}$ ounces
Fats	2 ounces
Carbohydrates	17 ounces

With these amounts as the basis of calculations, solve the following problems, referring when necessary to the table on page 243 of the textbook:

- a. If one should eat potatoes only, how much would he need to consume in a day in order to secure enough protein to meet his day's requirement?
- b. How much milk would be necessary to supply the needed protein if it were used exclusively as the day's food?
- c. Determine the same point, assuming that bread is the sole source of food.
- d. How much rice would be required for a day's protein food if nothing else were eaten?
- e. Which of the foods are the best-balanced with respect to the amounts of the three materials?

EXERCISE 87

WHAT ARE THE STAGES IN THE DEVELOPMENT OF THE FROG'S EGG?

Materials. Fresh eggs of the frog or toad (these may be secured in early spring, the toad's eggs usually appearing a little later than those of the frog); large aquarium jars; hand magnifying glasses.

Directions. Place the eggs of the frog or toad in an aquarium in shallow water. Observe them from day to day, noting early stages of development. Some of the eggs may be examined from day to day under the low power of a microscope. The following stages may be observed:

a. If the eggs are secured very soon after they are laid it will be possible to see, with a hand magnifier or under the low power of a microscope, some which have divided into 2 cells, 4 cells, or a larger number of cells.

b. At a later period the original single egg cell has divided into such a large number that the individual cells of the mass cannot be separately distinguished by use of the magnifier.

c. The mass of cells produced by the egg becomes elongated instead of spherical. This is called the embryo.

d. The embryo continues to elongate; head and tail may be distinguished; eyes and other organs appear.

e. The young animal frees itself from the surrounding jelly, swims through the water, and usually attaches itself to floating objects or to the walls of the aquarium. At this stage it has conspicuous gills (breathing organs).

Record and describe all the changes which you have observed in the development of the egg.

Additional problems. Can you discover how to distinguish frog's eggs from toad's eggs?

In what kinds of situations do these animals lay their eggs?

At approximately what dates are frog's and toad's eggs laid in your region?

Newts and salamanders are animals which are related to frogs and toads in structure and habits. If you can find their eggs, these animals may be grown in aquaria, as may frogs and toads.

EXERCISE 88

THE GROWTH AND DEVELOPMENT OF A TADPOLE

Materials. The materials of the preceding exercise.

Directions. Observe the tadpoles of the preceding experiment during several weeks. Record your observations, including the following points and questions:

- a.* Changes in form.
- b.* Feeding habits.
- c.* Growth.
- d.* Appearance of legs.
- e.* Disappearance of tail.
- f.* Evidences of air-breathing in later stages.
- g.* Emergence from water.

At what stage in the development of the tadpole do the gills disappear? When does the animal cease to attach itself constantly to some solid object? Which of the legs appears first? Are the first legs and the tail used at the same time in swimming? What becomes of the tail?

Additional problems. What is the food material of frogs and toads when they live on land?

Of what economic importance are toads?

Is the practice of destroying toads an intelligent practice?

EXERCISE 88A

THE DEVELOPMENT OF THE BIRD EMBRYO DURING THE HATCHING OF THE EGG

Materials. Two dozen hen's eggs; an incubator.

Directions. Place at least two dozen hen's eggs in an incubator which has previously been in operation until it is properly regulated. Open an egg on at least each of the following days of the incubating period: first day; second; third; fifth; eighth; twelfth; sixteenth. On the first day note the germ cell, or fertilized egg, lying close to the yolk, it being recognized by a reddish ring about it. In the other observations determine what changes have taken place in the eggs.

Additional problems. Why will eggs usually not hatch after they have been subjected to sudden and great changes in temperature? Why will eggs not hatch after they have been in cold storage?

How do you account for the fact that in a nest of young robins the birds hatch on successive days, while in a nest of quail or domestic fowls the young birds usually all hatch on the same day?

EXERCISE 89

THE STRUCTURE OF A SEED AND OF THE YOUNG PLANT

Materials. Seeds of bean, corn, or peanut; sawdust, sand, or common soil; earthen pots or small wooden boxes.

Directions. Plant seeds of bean, corn, or peanut at least two weeks before it is intended to make this study. If the seeds are planted in a glass jar near the sides, the sides being darkened by use of a black cloth, the growth may be observed during the process. Observe the plantings from time to time and record all facts of interest as the young plants "come up." When the plants have from two to four leaves, make your final study and description. At this time the young stem and roots, as well as the leaves, will have assumed definite form and their characteristic positions.

Soak seeds in water for about twenty-four hours and examine them to discover how many and what structures found in the seedling may be found also in the seed. Examine the seeds for evidence of stored food. What is the function of this food in the development of the young plant?

Additional problems. Plant ten or twelve different kinds of seeds, and as they grow determine the nature and variations in the seed leaves of these plants.

By use of a very sharp knife remove the seed leaves from some seedlings as soon as the seed leaves appear above the soil, and determine what effect this has upon the young plants.

EXERCISE 90

HOW RAPIDLY MAY PLANTS AND ANIMALS INCREASE UNDER ENTIRELY FAVORABLE CONDITIONS?

Materials. Ears of corn; heads of wheat or oats; seed pods of any common plants; data regarding number of eggs laid by a robin and a toad.

Directions. Determine how rapidly given plants or animals would increase in given lengths of time, if all seeds should grow each year in case of plants or if all the young of animals should mature.

It is suggested that each pupil perform but one or two of the determinations given below, and that the results of all determinations be made available to the entire class.

a. Indian corn. Count the rows and number of grains in a row on one ear. Estimate the number of grains on the ear. Calculate the descendants in the fifth generation.

b. Wheat. Ascertain the number of grains in a head and suppose that there are five heads to each plant. Calculate the number of grains in the fifth generation.

c. Robin. Assuming that a female robin will lay four eggs and that one half of the new birds will be females, calculate the number of robins at the end of ten years if all eggs hatch and no birds die.

d. Toad. A female toad may lay as many as 11,000 eggs. Assuming 8000 as a fair average and that one half the young toads will be females, calculate the number of toads from a single pair at the end of four generations if all the eggs hatch and no toads die.

Additional problems. Assuming that an average toad will weigh a quarter of a pound, what would be the weight of the four generations of toads according to the above estimate?

Why do not plants or animals really increase as rapidly as indicated by the above calculations?

EXERCISE 91

HOW DO EARS OF CORN DIFFER IN THE NUMBER OF GRAINS THEY HAVE?

Materials. A supply of ears of corn, so that each pupil may have one ear.

Directions. Each pupil should calculate the number of grains on one ear. In case grains have been lost, determine how many were lost and add this number to the number counted. Write the total upon the board, and also copy in your notebook the totals of all the other pupils. Underline the largest and smallest numbers and leave all the numbers for further use.

Additional problems. Do most of the ears used in the calculations come nearest to the smallest number, to the largest number, or midway between?

If you were selecting one ear for planting from all those used in the calculations, which one would you select? What qualities lead you to make your selection?

EXERCISE 92

HOW DO EARS OF CORN DIFFER IN WEIGHT?

Materials. Same as in Exercise 91.

Directions. Each pupil should weigh accurately one ear of corn and record the weight on the board at the side of the number of grains on this same ear. Copy all the weights in your notebook. Underline the heaviest and lightest ears. Are these ears the same ones which have respectively the largest and smallest number of grains?

Additional problems. Are most ears heavy, light, or medium?

Is your choice of the best ear for planting changed by the above calculation?

EXERCISE 93

WHAT IS THE RELATION BETWEEN THE WEIGHT OF THE GRAINS AND THAT OF
THE COB IN EARS OF CORN?

Materials. Same as in Exercises 91 and 92.

Directions. Weigh the ear. Shell the grains from the cob. Be careful to lose none. Weigh the grains and record the weight, using the blanks given below. Weigh the cob. Add the two weights, and if they do not correspond with the total weight of the ear (Exercise 92), try to discover your error.

Weight of ear	
Weight of grains	
Weight of cob	
Sum of grains and cob	
Difference	

Place the weights of grains and cob on the board at the sides of the corresponding figures for each ear. Underline the ear having the largest weight of grains; largest weight of cob; smallest weight of grains; smallest weight of cob.

Additional problems. What percentage of the total weight of the ear is the weight of the grains? Record this percentage at the side of corresponding numbers for the ear. Underline the highest and the lowest percentage of grains to total weight. In the light of all facts shown, which ear would you now select as the best for planting?

Could you select from the above data any combination of characteristics which would appear better than any combination which was found?

EXERCISE 94

ARE VARIATIONS IN PARENTS TRANSMITTED TO OFFSPRING ?

Materials. The table given below shows the height of 928 persons whose records were studied by Francis Galton. It is so arranged that the heights of these individuals may be compared with the heights of their parents, and the inheritance of stature may thus be seen.

Directions. In the third horizontal space from the top the figures given indicate the size-groups in which the children are classified. The vertical column at the left (column 1) gives the heights of the parents, the heading "mid-parental height" meaning the middle point between the heights of the two parents in a family.

MID-PARENTAL HEIGHT		HEIGHTS OF ADULT CHILDREN														
1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		61.2 and below	62.2	63.2	64.2	65.2	66.2	67.2	68.2	69.2	70.2	71.2	72.2	73.2	74.2 and above	MEAN OF CHILDREN
a	72.5 and above												1	3		72.95
b	72.5								1	2	1	2	7	2	4	71.4
c	71.5					1	3	4	3	5	10	4	9	2	2	69.9
d	70.5	1		1		1	1	3	12	18	14	7	4	3	3	69.5
e	69.5			1	16	4	17	27	20	33	25	20	11	4	5	68.6
f	68.5	1		7	11	16	25	31	34	48	21	18	4	3		68.0
g	67.5		3	5	14	15	36	38	28	38	19	11	4			67.6
h	66.5		3	3	5	2	17	17	14	13	4					67.1
i	65.5	1		9	5	7	11	11	7	7	5	2	1			66.8
j	64.5	1	1	4	4	1	5	5		2						65.6
k	63.5 and below	1		2	4	1	2	2	1	1						65.6

In column 16 at the right the figures in each space represent the average height of all children of parents of the heights indicated in the corresponding space in column 1. The other figures of the table indicate the distribution of the children. The way in which the table is read is indicated by the following examples:

Column 3 shows that among the seven persons whose heights were near 62.2 inches there were three from families in which the mid-parental height was 67.5; three from families with a parental average of 66.5; and one from a family in which the parental average was 64.5.

Line b shows that in all the families in which the mid-parental height was 72.5 inches one child had a height, when adult, of about 68.2 inches; two were 69.2 inches tall; one was 70.2; two were 71.2; seven belonged to the 72.2 group; two belonged to the 73.2 group; and four were taller than any of these.

Examine line f. Observe and state how wide is the variation. Note how many children are taller than their parents, how many are shorter, and how many are nearly of the parental height.

EXERCISE 94 (Continued)

Do you find that many of the children closely resemble the parents in height? Before you draw any conclusions look over lines **c** and **j** and other lines, to see whether the relations you find in line **f** are generally true.

So far as you can determine by this study, what do you think about the probable average resemblance of a child to its parents? Try to write your conclusion in the form of a general rule about the likeness of the offspring to parents.

Additional problems. Compare the average heights of parents (column 1, **b** to **j**) with average heights of their children (column 16). Find the difference between these figures in each horizontal line, marking the differences by the plus sign (+) if the children average taller than their parents and by the minus sign (−) if they are shorter. Do the children of unusually tall parents average more unusual than their parents or less unusual? Are children of unusually tall parents taller than the average of all? Are any of them taller than their parents? Make the same study regarding the unusually short persons. In general, do the children of unusual parents average as unusual as the parents?

If the rule of inheritance shown above holds good for such characteristics as mental ability, moral tendencies, tendencies toward insanity and feeble-mindedness, what is the advantage of being "well-born"?

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